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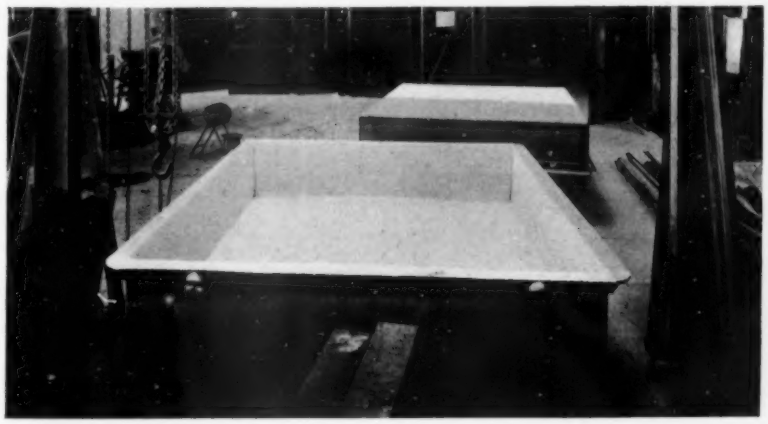
Metal Spraying as a Protection against Corrosion

By W. E. Ballard

The process of spraying a less-corrodible metal on iron and steel structures has many advantages and its field of application is gradually increasing. In this article the process is briefly explained and its applications outlined.

THE protection of metals against corrosion constitutes one of the most difficult engineering problems, and its economic importance, particularly in regard to iron and steel, is familiar to engineers and others who have experience of metal structures. In view of the loss sustained as a result of the corrosion of metals, it is not surprising that much attention has been directed to the problem in order to afford protection against this loss. During recent years especially, much valuable and successful research work has been carried out on the subject, not only with the object of elucidating the factors that determine the rate and character of corrosion in any particular case, but also to seek fundamental causes and apply remedies. Apart from the use of alloying elements in iron and steel, which reduce their corrosive tendencies, one of two methods is generally applied: by means of thin oxide film or by treating the surface of the metal, covering it with a material less resistant to corrosion.



Large aluminised salt baths.

Much research work has been conducted during recent years on the properties and isolation of thin films which form spontaneously on metals under certain conditions, and which protects them from further attack. The most commonly used method of affording protection, however, is by means of a layer of another less-corrodible metal, or by a film of paint, varnish, or bituminous material; but each method employed is founded on scientific principles, any departure from which will give uncertain results. In this article it is proposed to consider artificially applied protective coatings, rather than spontaneous films, in regard to which uniformity and perfect continuity over the whole surface of the metal treated is essential, and to deal more particularly with the process of metal spraying.

The process most commonly used for the protection of iron and steel is undoubtedly that involving the application of some form of paint. This process offers certain economic advantages, and with care in the selection of the paint, together with its application under the most suitable conditions, it will offer considerable protection against corrosion and lengthen the life of the structure. It is necessary, however, to renew the paint film at frequent intervals if protection is to be adequate, and the cost involved over a number of years, especially in the case of large structures, is considerable.

Generally, better protection can be obtained by the use of metallic coverings, such as those obtained in hot galvanising and dip tinning, or by the penetration of the surface of the steel by another metal, such as in the process of sherardising. Unfortunately, these methods are not usually applicable to large structures, and have the disadvantage that the parts treated must be heated to a considerable temperature. Films of protective metals can be applied by electro-deposition without heat-treatment, but the size of the articles treated is limited by vat size, and the acid used in cleaning frequently gives trouble in service.

The value of zinc as a protective covering for iron and steel is now universally appreciated. Zinc coverings have a very long life, although the protection afforded is due to sacrificial action—*i.e.*, the zinc slowly dissolving in preference to the iron base. The protection is better if the coating of zinc is of high purity, and, providing it is possible to obtain a pure zinc coating, applied cold by a method which is applicable to large structures, it will be appreciated that such a method would go far towards satisfying the need for absolute protection.

Such a method is available to commerce and is known as metal spraying. In this system a special tool is used which consists essentially of a blowpipe through which the zinc wire is passed. As the wire enters the flame it melts, but as the blowpipe flame is surrounded by a stream of compressed air the molten metal is blown forward as a fine spray. The special tool, known as the "pistol," is fitted with a turbine driven by compressed air, and this turbine actuates gears moving small rolls which pull in the wire from the roll or hank. The pistol weighs about 3½ lb., and is no more difficult to use than a paint-spraying gun. Full detailed descriptions of the tool have appeared many times in the technical press, and it is therefore not proposed to describe it more fully here. Sufficient is it to say that the pistol is fed with compressed air at from 35—50 lb. per

sq. in. pressure, oxygen under pressure, and a combustible gas under pressure, such as hydrogen, coal gas, or acetylene, the latter from cylinders of the dissolved gas. It will be seen that the tool is extremely portable, and it is noteworthy that another type of nozzle may be fitted to the pistol, which allows the tool to be used for spraying internally straight tubes down to 1¼ in. diameter.

The metal leaving the pistol is in the form of a fine mist, which will stick to any surface suitably cleaned and roughened. The outer envelope of compressed air rapidly dissipates the heat of the flame so that the hand may be held in the jet without discomfort, and surfaces such as celluloid and cloth can be treated without damage.

For treating iron and steel the surfaces to be coated have first to be sandblasted. This process can be conveniently carried out even *in situ*, and this mode of preparation

Zinc spraying a large tank.

has the advantage that by avoiding the use of acids there is no danger of "spotting out" in service. The sandblasting is necessary in order to clean the surface and also in order to give an open texture, because there is no chemical combination or alloying of the sprayed coating to the base metal, the adhesion being about seven tons to the square inch.

The coatings obtained by this process are matte, and the coatings follow the contour of the work exactly. There are no conglomerations of excess metal in any crevices. The coatings can be applied to almost any thickness by increasing the time of application. It is found, in practice, that a coating of four thousandths of an inch of zinc gives a protective film which under atmospheric conditions outlasts ordinary hot galvanising many times.

Riveted structures can be coated after erection, and so bad spots are avoided. On flat surfaces of light weight, such as the corrugated sheets of commerce, spraying is more expensive than hot galvanising, but on heavier articles, where the surface area is more in proportion to the weight, spraying is often even initially the cheapest form of protection known. As the process is cold there is no danger of distortion, neither on cast iron is there any danger of cracking, even if the castings have a very thin section.

It may be thought that as the spraying takes place in a severely oxidising atmosphere the coatings will be full of oxide. This is not so, as, apparently, the time taken for the metallic particles to transverse the spraying distance of 5 in. is so small that oxidation is limited. For instance, a brass wire sprayed through the pistol loses only so small a proportion of zinc that the composition of the coating is very nearly identical with that of the wire.

With all processes of this nature the question which is naturally asked is: "Are these coatings commercially used?" The answer in this case is definitely in the affirmative. Although the process is comparatively new many hundreds of tons of steel are protected by this method in this country, and the use is ever increasing.

A few instances of the use of zinc coatings can now be given. Metal spraying has been used for the protection of railway bridges, the work being done *in situ*. The large tanks used in the manufacture of acetate silk are usually treated in this way. Such tanks and those used for storing aviation spirit are much too large for galvanising. Filter-press plates for various industries where galvanising has failed have been successfully used for years after spraying. Zinc spraying is also being used increasingly for hydro-extractor cages, the balance of which is not affected by coating. Outside switchgear, transforming stations, and transmission towers are also being treated. The large cast-iron parts of penstocks and lock gates have also been treated, with very good results, as have also ships' deck fittings, anchors, etc.

A good example of the use of zinc spraying is the steel-window industry, where the process has been used for some years by the Crittall Manufacturing Company on their "Zincspra" windows. Metallised zinc surfaces are an ideal base for paint, so differing from hot galvanising. Owing to the matte finish paint or cellulose does not crack or peel from the surface, and owing to the reducing nature of the zinc the paint keeps its colour better. Even on wood it often pays to use zinc spray as a priming coat where a high finish is required.

It has been noted before that the pistol is able to spray brass as well as zinc, and it is well to make it clear at this point that the pistol can deal with any metal or alloy which can be drawn into wire and melted in the oxy-acetylene flame.

The process therefore gives the only commercial method of depositing the metal aluminium as a coating. This allows the coating of articles to be exposed to sulphurous atmospheres with this metal which resists such conditions extremely well. An instance may be given in the treatment of gas-holder shells, to resist the action of the sulphur compounds in the water seal.

A problem of metallurgical interest is the treatment of light alloys of aluminium such as duralumin with pure aluminium, so increasing their resistance to corrosion. Aluminium coatings often replace the more expensive ones of tin in food-producing machinery, and in machinery dealing with milk products.

The coatings of aluminium on steel are also extremely resistant to atmospheric corrosion, especially under some circumstances.

Aluminium coatings on steel are also very resistant to temperatures up to 400° C., and retain their colour almost indefinitely up to this range. Out of the use of aluminium for the treatment of exhaust manifolds of motors came the very important process of aluminising.

Aluminising is a process of great metallurgical significance and consists of aluminium spraying and a subsequent heat-treatment. The aluminium coating alloys with the steel base giving a grey-iron aluminium alloy. This alloy on heating oxidises on the surface, giving a film of aluminium oxide which protects the underlying metal from further oxidation. These iron-aluminium skins, formed by varying methods, have been used for some years for protection against heat, but aluminising by spraying is the cheapest method of obtaining the results, and the size of the article is not limited.

The aluminium-iron alloy skin is effective as a protection to temperatures of about 975° C., but above this temperature the penetration of the aluminium into the iron is so rapid that protection cannot be relied upon. Aluminising is also applicable to cast iron so long as the iron is of a mixture which is not subject to excessive growth under oxidising conditions. From a metallurgical standpoint it is interesting to note that steel containing high oxygen

contents, or rolled in scale in excessive quantities, cannot be aluminised successfully, as the oxygen prevents the penetration of the aluminium. Aluminising might therefore be a convenient test for excessive oxygen content in steels.

Aluminising has now been adopted as a standard method by the Air Ministry of treating the exhaust rings of aircraft as the coating resists atmospheric corrosion as well as high temperatures. This process is also used extensively on casehardening boxes, cyanide pots, salt baths, and annealing pans. Another use which has proved very popular is the treatment of the outside of pots used in the bright annealing of non-ferrous wires. Aluminised steel is also used in place of the more expensive nickel chromes for fusing bars used in vitreous enamelling.

More recently aluminising has been adopted by several makers of electric furnaces for the protection of the steel parts. Superheaters, soot-blowers, and chain links of mechanical stokers are also treated; in fact, the superheaters of the German star ships—the *Bremen* and *Europa*—were protected in this way.

It is also interesting to note that at temperatures exceeding 1,000° C., where nickel-chromium alloys have to be used, aluminising is often used on these alloys because it prevents the sulphurisation which sometimes brings about their disruption in furnace atmospheres. In certain cases it has also been found beneficial to aluminise the surfaces of ingot moulds used for non-ferrous metals.

Enough has been said to make it apparent that metal spraying also has another advantage in that coatings of layers of different metals can be applied, and some of these mixed metal coatings have extraordinary properties of resisting special types of attack.

It is well known that ordinary thinly tinned copper sheets when used in dairy plant lose their tin quickly, and metal spraying gives a method by which such apparatus can be re-tinned quickly without fear of distortion. The tin coatings are applied to a thickness of five to ten thousandths of an inch, and have a life greatly in excess of the ordinary wiped tin, which is usually very much thinner.

As before-mentioned, metal-sprayed coatings have a fine matte surface, which at one time was distrusted by those engaged in industries where bacteria is important. It was felt that such coatings might not be easily cleaned and sterilised. This fear is found to be without foundation in practice, and the use of sprayed tin in vessels for food manufacture is growing. The spraying of lead is also a commercial proposition, but is not sought after as the pistol generates a fine metallic dust which is extremely toxic. Men engaged in the spraying of lead have, therefore, to be specially protected. A thin lead coating is of great use in the prevention of pitting of propellers, etc.

Coatings of nickel, applied by the spray process, also find a considerable outlet in those cases where expense is not the primary consideration. Such a case is that of certain rolls used in the manufacture of paper. These are coated with two to three hundredths of an inch of nickel and ground to a very high finish. Such rolls have been perfectly satisfactory in the presence of alum and dilute chromic acid.

General view of a typical metal spraying works.

In the space given to this article it is impossible to do more than outline the uses of the metal-spraying process, even when used as a protective measure against corrosive influences, and it is therefore not possible to touch on its use for reclaiming castings, screening wireless apparatus, prevention of corona on insulators, and "pinking" in motor cylinders, etc., etc.; but metal spraying has many more commercial uses than it is possible to mention here.

The Practice of Spectrum Analysis

SPECTRUM analysis as it exists to-day provides a rapid means of determining the entire metallic constituents of any substance. Powders, liquids, alloys, plant, and vegetable fibres, no matter how complex, or whether the amount be large or small, all yield to the one technique, with slight variations according to the nature of the substance examined, and a full and permanent record is obtained of whatever metals are contained. In alloys, powders, and solutions the metallic contents can be quantitatively determined, usually with an accuracy of about 5 to 10% of the percentage of each metal present, when suitable means are employed. With modern instruments the technique is readily grasped, and the speed of determination is very rapid.

Progress in the application of this form of analysis has created a steady demand for this practical treatise on the subject, and the production of a further edition, the sixth, has become necessary. With this edition the opportunity afforded has been employed to effect a very thorough revision of the work. Whilst the chapter headings remain practically unchanged the chapters themselves have been overhauled and matter which has passed its period of usefulness rejected. This has enabled a considerable bulk of new material to be included without increasing to any marked extent the size of the book.

The main alterations are to be found in the chapter dealing with quantitative spectrum analysis, and the recent advances in this part of the field are covered in detail. The use of the logarithmic wedge sector is discussed at length and the work done by its means is reviewed. The use of the microphotometer comes in for examination, whilst other aspects of the subject to which attention is devoted are the new ratio quantitative system and the possible attainment of higher accuracy in quantitative analysis.

In other sections the discussion of, for example, the photographic plate and its characteristics has been extended, whilst entirely new material appears in the form of notes on the effect of polarity in the arc, on the preliminary treatment of specimens, etc. Throughout, the endeavour has been made to render the book as useful as possible to the man who uses the spectrograph.

Compiled by F. TWYMAN, F.Inst.P., F.R.S., and published by Adam Hilger, Ltd., 98, King's Road, Camden Road, London, N.W. 1. Price, 3s. 6d. net; 3s. 8d. post free.

Reviews of Current Literature.

The Metallographpy of Iron and Steel

IT is probably true that there is a certain class of sound practical men in the various branches of the iron and steel industry who have a prejudice against theoretical knowledge, but gradually it is being appreciated that the successful application of theoretical knowledge is making possible the remarkable progress in the development of metals and alloys to meet modern conditions of service. The industrial value of alloys, for instance, depends largely upon their chemical composition and their physical constitution or structure, and it is only by the application of theoretical knowledge that alloys can be studied to determine their chemical composition and structure, and subsequently to study the relation existing between these factors and their useful properties.

No one method is sufficient to provide a solution to all the problems associated with the constitution of alloys, and, therefore, all methods which give useful information are used, and in this book the author gives a general survey of the theoretical metallurgy of iron and steel in its latest form. It is given in such a form that the practical man can readily understand the most advanced aspect of the subject. The matter is presented in a very attractive form, and the author is to be congratulated on the successful way in which he has contrived to cover a wide field in a manner that will not only appeal to the practical man but supply him with easily understood information that is not so readily absorbed from other sources.

The literature on the metallurgy of iron and steel is rich and provides a wealth of information for the discriminating metallurgist or student. Few books, however, explain the fundamental principles in a sufficiently lucid manner for the practical man, and this new work is designed to fill this need. There can be no doubt that the initial difficulties of the student or practical man in grasping fundamental principles and meaning of terms used in metallurgy are very considerable, and any work likely to remove many of these difficulties is more than welcome.

In various chapters the author discusses equilibrium diagrams, cooling curves, and crystallisation; wrought iron, steel, and cast iron are dealt with separately and distinctly as separate products of the iron-carbon group; a representative description of the microstructure of iron and steel, and methods are indicated that should be adopted in the examination of these materials by means of the microscope; macrographic examination of metals is discussed as also is the application of X-rays for that purpose; mechanical tests and mechanical properties are explained in separate chapters, and the question of corrosion is discussed. The book is admirably produced and should prove of considerable value to the student and of great assistance to the practical man.

By C. HUBERT PLANT, F.I.A.C. Published by Sir Isaac Pitman and Sons, Ltd., Parker Street, Kingsway, London, W.C. 2. Price, 12s. 6d. net.

Alloys of Iron and Molybdenum

THIS book is the first of a monograph series dealing with the alloys of iron, and is confined to molybdenum and other alloys of molybdenum and iron, with or without additional alloying elements. About 800 articles have been studied in detail, and specially abstracted for the information included in this work, and in order to fill the gaps in this information research has been necessary. The existing literature revealed the fact that investigators were interested chiefly in the effect of molybdenum on steel and cast iron rather than the constitution of the pure alloys, and it is in this direction that much research work has been necessary. The task of collecting the data must have been a formidable one, and the author is deserving of every praise for the excellent manner in which he has assembled the information and data at his disposal.

The subject matter is admirably arranged. It is conveniently subdivided into chapters in which the author discusses molybdenum minerals and ores, the iron-molybdenum alloy systems, and the manufacture and working of molybdenum steel together with its properties and uses. The book also contains a very complete review of the effect of molybdenum in high-speed steel, in nitriding steel, and cast iron. An interesting and useful innovation is the author's summary at the conclusion of almost every chapter. These are particularly helpful in the assimilation of many facts resulting from research and are of considerable assistance for reference purposes.

The functions of molybdenum in a steel are essentially to exert a powerful influence in improving the physical qualities, in promoting fine grain structure, in eliminating temper brittleness, in reducing the effect of mass, and in giving permanency to the physical properties which enable the steel to resist abnormal conditions during service and when subjected to wide temperature variations; but to ensure that these results will be obtained in practice, it is necessary to be familiar with the amount of molybdenum required in relation to other elements, and this book supplies practically all the available information to this end.

Although molybdenum owes its importance primarily to its value as an alloying element in steel, it has definitely become established as an invaluable element in improving grey cast iron and malleable cast iron. Data given in this show remarkably high physical properties achieved in cast iron alloyed with molybdenum. While for many purposes it is probable that the merits of this element can only be ascertained in actual practice, there is ample evidence to show that considerable success is being achieved, and its increasing application in the manufacture of high-duty castings indicates that difficulties inseparable from new applications are now practically overcome in regard to molybdenum cast irons.

The book is well illustrated, and the tables of mechanical tests, supported by graphs are a useful feature. In addition to a bibliography which contains 515 references, name and subject indexes are included. It is published under the auspices of the Iron Alloys Committee of the Engineering Foundation, and the high standard of this the first book of a series to be published will encourage readers to look forward to future issues with more than usual interest. This book should prove invaluable to the practical metallurgist, steelworker, foundryman, and engineer for reference purposes, while students will find it a useful source of information on alloy steels. In addition, the book provides a valuable basis for further research since it contains a correlated résumé of all important previous investigations on the simple and complex alloys of iron and molybdenum.

By J. L. GREGG. Published for The Engineering Foundation by McGraw-Hill Publishing Co., Ltd., Aldwych House, London, W.C. 2. Price, 36s. net.

Handbook for Oxy-Acetylene Welders

THIS handbook has been compiled as a book of reference and instruction for all engaged in oxy-acetylene welding operations, both in the practical work of welding and in a directional capacity. It sets out such data and information, in non-technical language, that should enable the welder to perform good work and avoid the mistakes which the beginner is liable to make. This volume brings up to date much of the information contained in the handbook by Leonard M. Fox, the second edition of which was published by Allen-Liversidge, Ltd., in October, 1928.

A new and useful feature is the introduction of certain blank pages headed "Welder's Notes" which will be a great convenience to users of this handbook, since it will enable them to add notes resulting from their own experience or information from the technical press which may assist towards overcoming unusual difficulties presented from time to time in producing satisfactory welds. Illustrations supplement the text and are well produced. The valuable practical information contained in this handbook makes it worthy of possession by all associated with welding.

Published by the British Oxygen Co., Ltd., Angel Road, Upper Edmonton, London, N. 18. Price, 3s. 6d.

The Need and Development of Measurement in the Steel Industry

By G. H. Barker

"Progress in the technological industries is bounded by the applications of physical science—the science of measurements. The more any industry "goes scientific" the greater the number of magnitudes, rates and quantities it must measure in order to secure the practical basis for controlling that which is measured."

DURING recent years there has been a remarkable extension of the application of measuring and controlling instruments to iron and steel-works processes, and the subsequent treatment of the metals produced in the course of their subordination to their infinite variety of uses. More stringent specifications have stimulated and enforced technical improvement, whilst intensified expert competition has made reductions in production cost imperative. Both requirements have extended the field of measurement and process control.

The modern coking and blast-furnace plant, for example, is now equipped with the means of measurement of volume, temperature, suction, and pressure at practically every stage, with a resultant large increase in plant and labour efficiency, and lower working costs. The majority of these measurements, and particularly those of suction, pressure, and temperature, are too commonplace to require description or emphasis of their importance. Many are indispensable, even if the question of efficiency is ignored. The more widespread employment of fully automatic flow, pressure, and suction regulators on gas and steam mains, chimneys, and for regenerator reversals, however, should be noted. Fig. 1 shows a typical regulator of the motor-driven, oil-servo-motor type, for these duties. Automatic regulation of this character is simple and reliable, and ample evidence is available to prove its efficiency.

Fig. 1.—Automatic regulator of the motor-driven, oil-servo-motor type.

The volumetric measurement of raw and softened water, high and low-pressure steam supplies, fuel and surplus gas, etc., has extended with the growing recognition of the importance, economically, of exact knowledge of production and employment. Industrial cost accountancy is acquiring its full importance, and has been fostered by improvement in the methods of measurement.

Fig. 2 shows an electrically-operated multiple gas and steam metering system installed at the Irlam works of the Lancashire Steel Corporation. Centralised, co-ordinated measurement of this type frees the superintending engineers from the restrictions inseparable from the earlier types of mechanical flow meters which had, of necessity, to be installed at or near the various measuring points. In association with the centralised totalisers and multiple recorders are large dial rate-of-flow indicators at the control platforms, for the guidance of operators.

One of the most interesting of the newer trends, associated with automatic pressure regulation, is the fully automatic control of gas mixing, or the development of what may be termed a gas-grid system in the larger works operating coking and by-product plant, blast-furnaces, and steel mills as comprehensive production units. The mixture of coke-oven gas, with a calorific value of, say, 450/500 B.th.u. per cubic foot, and blast-furnace gas at 110/120 B.th.u. to produce a gas of a value of, say, 250 B.th.u., can now be automatically regulated with acceptable efficiency and reliability. Differential media (normally thin, concentric orifice plates) are inserted in the gas mains. The differential pressures are transmitted to two sensitive diaphragms, these diaphragms acting as flow meters. The diaphragms are connected through an adjustable differential linkage to the pilot valve of a regulator similar to that illustrated by Fig. 1. The required ratio having been determined, the differential linkage is so adjusted by the means provided that so long as the ratio remains constant (whatever the actual rates of flow) the pilot valve of the regulator remains in its neutral position. When a departure from the predetermined ratio occurs, the pilot valve alters the admission of oil to the relay cylinder of the regulator, which, in turn, alters the setting of the controlling valve, thus restoring the original ratio.

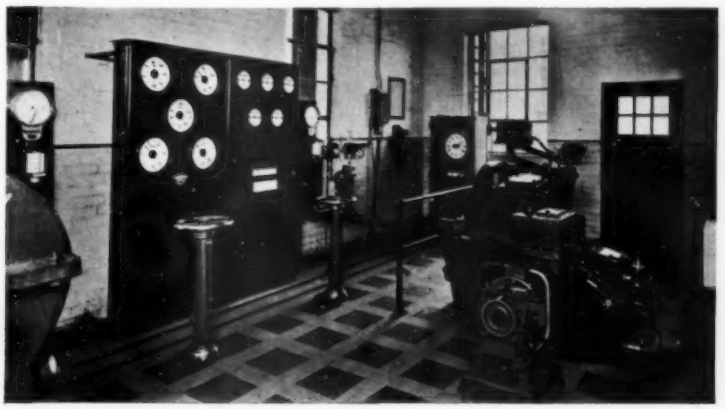


Fig. 2.—Typical electrically-operated multiple gas and steam metering system.

A similar system is employed for the automatic proportioning of gas to air for combustion purposes. An automatic ratio indicator may be incorporated, together with meters (operating from the same differential media) to measure the respective flows. Fig. 3 illustrates a typical arrangement.

Automatic control has also been applied to the blast-furnace, in the sense that it is now fairly common practice to regulate the temperature of the hot blast by automatically altering the setting of the cold air mixer valve to correct deviations from the correct temperature. The efficiency of the system is evidenced by its ability to hold the temperature within + or − 8° F., with brief, rapidly corrected variations as new stoves are put on air. Increased more uniform production, with reduced coke consumption and lower labour costs result. Fig. 4 illustrates the indicating

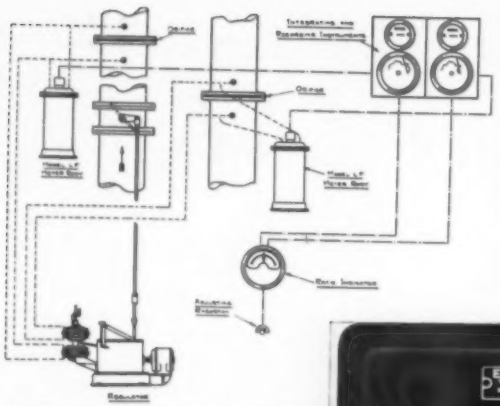


Fig. 3.—Typical gas and air flow ratio regulator system.

control pyrometer, which is the essential part of this system.

Complete equipment for the blast-furnace will also include a two-point recording pyrometer for the hot-blast main and downcomer temperatures, and a similar multi-point instrument for the stove gas and air temperatures. A typical instrument is shown by Fig. 5. The gas, and frequently the air, to the stoves is also metered.

In the steelworks the chief interest at the moment is in the application of instrument equipment for the semi- or fully automatic reversal of open-hearth furnaces on the basis of temperature difference, this employment of measuring and controlling instruments ensuring the minimum fuel consumption with best output, and longest chequer life. It has long been recognised that the reversal of regenerative furnaces on a time-cycle basis is wrong, inasmuch as heat conditions within the furnace change so rapidly that not only is there a correct point for reversal, but this point is variable with every furnace and each reversal during any one heat.

The temperature difference method of determining the correct point of reversal comprises the installation of two thermocouples in the air flues, or cold-end chequer walls connected in opposition to a thermo-electric control pyrometer. The instrument therefore reads the number of degrees temperature difference between the two, the control index being set at the particular difference at which experience has shown reversal should occur. When the indicating pointer coincides with the control index, the control mechanism energises the circuit of a warning lamp and Klaxon horn, whereupon the furnace is reversed manually. The polarity of the thermocouples is reversed by a trip-switch during this operation, so that the same cycle of events is repeated in the opposite direction.

Majority opinion is that a warning system of this kind is to be preferred to a fully automatic system, for the reason that it cannot take account of those external conditions—*e.g.* uneven melting,—which may make a delay in reversal desirable. However, fully automatic equipment is available to give the impulse to electric, hydraulic or pneumatic reversing gear, the control pyrometer being employed in conjunction with a reversing motor-driven regulator in the case of hydraulic or pneumatic gear. The system also comprises a two-point temperature recorder showing the actual temperatures reached by the thermocouples, and the points of reversal. Fig. 6 shows a typical outfit of the alarm type, whilst Fig. 7 shows one of several instrument panels with suction and pressure indicators, CO_2 recorders, regenerator temperature, and waste gas temperature recorders, etc., recently applied to open-hearth steel furnaces at a well-known British steelworks.

Indisputably, the instrumentation of steelworks and associated plant along the lines described rapidly returns its cost many times over through reduced fuel and labour charges and product improvement, whilst it frees operatives from much drudgery and thereby stimulates their interest in the processes they control.

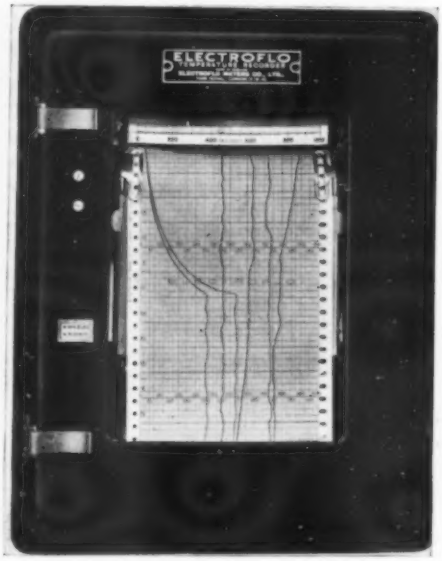
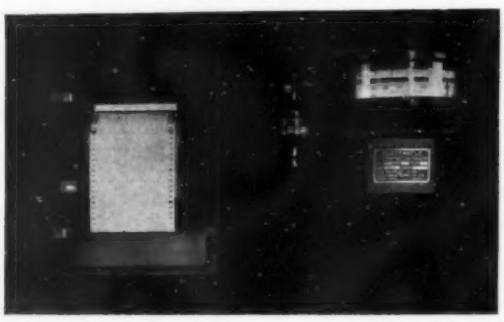


Fig. 5.—Typical two-point recording pyrometer.

Fig. 7.—Typical instrument panel with suction and pressure indicators, CO_2 recorders, regenerator temperature, and waste gas temperature recorders, etc.

Fig. 4.—An indicating control pyrometer.

Fig. 6.—Typical temperature recorder outfit of the alarm type.



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METALLURGIA

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TRADE OPTIMISM IS PREVALENT

FURTHER reduction in the number of unemployed, and improved trade prospects, which even include some of the basic industries, is the cheering news accounting for a perceptible rise in the spirits of many people today. Even the Chancellor of the Exchequer is viewing the Budget prospects with somewhat akin to rosy optimism, and suggesting that they are certainly more encouraging. Actually, there has been a gradual reduction in the number of unemployed since the early months of the year, and the latest returns show that a further 144,771 people resumed employment from those officially recognised as unemployed at the end of May. The total number of unemployed at the end of June was 2,438,108, which was 308,235 less than a year ago. An encouraging feature of this improvement is that the better conditions are spread over the great majority of industries, including several in which the depression has been most acute. The official figures, for instance, show improvement in the iron and steel industries, engineering, shipbuilding, and the textile industry.

There are distinct indications that this gradual recovery is the prelude to more prosperous times. Substantial progress has been made in the promotion of trade agreements with other countries. Agreements have been entered into with Denmark, Sweden, and, at the express invitation of the Finnish Government, there is to be a British Week in Finland from September 4 to 10, the object being to promote the sale of British manufactures. Thanks to the pertinacious efforts of Mr. Litvinov and the freeing of Messrs. Thornton and Macdonald, the negotiations for an Anglo-Russian commercial treaty have been resumed at the Board of Trade. Although they are to be resumed at the point where they were abruptly terminated by the April trial, the atmosphere will be better, and we believe a more conciliatory spirit will be engendered. In addition, however, the signs of trade recovery noticeable in several countries will tend to hasten the negotiations to a useful solution, as both countries can profit from an equitable arrangement. The primary object of these trade agreements and treaties is to promote interchange of trade on a reciprocal basis, and once adequate arrangements have been made with all those countries from which we take considerable supplies of food and merchandise we shall continue to exhibit the same signs of recovery.

It seems apparent that the Ottawa Conference has benefited some of the countries embraced by the agreements reached; the preferential tariffs seem to have facilitated exports to Great Britain but in some cases, the increase in reciprocal export from this country is not so apparent. Much as it is desirable to promote trade within the Empire, it should be done in the spirit of equity and justice, and in view of the relatively slow progress made since the Conference at Ottawa, there has been an increasing desire to open up trade negotiations with foreign countries. The success that has attended the efforts are in a measure responsible for the present improved outlook, and the Government is to be congratulated for its efforts to promote this international trade.

Another contributory cause of the optimism is reflected in the improved demand for iron and steel. In practically all the steel-producing districts there is an improved tone. During the first six months of this year, for instance, the English Steel Corporation, Ltd., have received orders to a value of £271,000 in excess of the similar period last year. In the Scunthorpe area the output of steel has been substantially increased in comparison with the first half of last year; at one of the works, a subsidiary of United Steel Companies, Ltd., the output has been almost doubled. Many of these firms are benefiting from reorganisation and reconstruction which has been effected during recent years, and it is of interest to note that the Lancashire Steel Corporation, Ltd., whose recent developments are discussed in this issue, are producing 500 tons of steel per week. There is an improved demand for steel in South Staffordshire, and to a lesser extent for iron. The increasing demand for steel is due in a measure to the curtailment of imported steel as a result of protective duties, but increasing orders from consumers at home and abroad have had a distinct influence and indicate an all-round improvement.

The maintenance of the upward tendency in shipbuilding is encouraging; the returns of Lloyds Register of Shipping for June 30 show that on that date there were under construction in Great Britain and Ireland 84 merchant vessels of 287,502 tons gross, which represents an increase of 16 ships and 35,101 tons on the figures of the previous quarter. The state of British shipbuilding is actually better than these figures indicate, since they only refer to merchant vessels, and important contracts for ships and engines have been placed this year by the Admiralty, representing large portions of the Naval programme of 1931 and 1932 which were postponed on account of economy. In addition, orders have been placed this year with British shipbuilding firms for war vessels for foreign nations and for the Australian Commonwealth.

Substantial contracts placed with British firms recently are hopeful signs for the immediate future. Of these mention may be made of the important contract for the electrification and completion of the main Warsaw railway junction. This contract, which is valued at about 60,000,000 zlotys (£1,980,000), has been signed in London between the Polish Under-Secretary for State in the Ministry of Finance, M. Koc (Chief Polish delegate to the Monetary and Economic Conference), on the one hand, and the English Electric Co., Ltd., and Metropolitan-Vickers Electrical Co., Ltd., on the other. It is stated that the work is to be carried out during the next four years, and part of the equipment will be supplied by these two British firms. In addition, there are indications that Metropolitan-Vickers will participate in the £3,000,000 railway contract for Rio de Janeiro. Further work is likely to be involved as a result of the steel merger on Tees-side, since the scheme includes arrangements for the issue of new capital to the extent of £2,230,000. Although much of this capital is required to provide for payments to be made under the amalgamation, a large balance will be left for new equipment and works improvements contemplated. The new blast-furnace plant to be erected in Scotland is another

indication of returning confidence, and a happy augury for the future of British industry.

It has only been possible to mention some of the outstanding features which tend to promote a more optimistic tone in regard to industry, and while they indicate that a distinct change for the better is apparent, actual signs of recovery in many trades are still few. Recovery seems to be more noticeable in those industries whose raw materials have recently risen in price, and it is probable that the move to this end will stimulate industrial activity and thus maintain the cheerful optimism which is so contagious.

It is assumed too readily by many people that the World Economic Conference has had no influence in these signs of trade recovery; that, in fact, the deliberations have been futile. Many business men have expressed the opinion that the return to normal conditions will come in spite of the London or any other conferences that may be held. That may be true, but he would have been a super idealist who expected agreement to a common plan from an assembly of about 2,000 delegates, representing nearly seventy nations, with their varying customs and traditions. The Conference has, however, afforded an opportunity for private meetings and consultations which has led to a better understanding of difficulties and efforts being made to overcome them, and it is probable that these meetings have had a greater influence on the optimistic trend than many people realise.

The improvement manifest, on reference to which Mr. Chamberlain was loudly cheered in the House of Commons, must be due to slightly increased consumption, upon which manufacturing countries like Britain depend, and if we look upon the changed conditions as a beginning, with goodwill predominating and the peace of the world remaining undisturbed, it may well lead to a slow re-establishment of industry and a gradual reduction in the number of unemployed, when despondency will continue to be displaced by cheerfulness.

Proposed Founding Degree.

THE Institute of British Foundrymen, through its enterprising and energetic Council, has worked strenuously during recent years to promote comprehensive training in foundry technology, and now it seems that its endeavours are to be crowned with success by a proposed university course in the subject. Such a course would eventually have an influence in raising the status of the industry to a position comparable with many other industries that set a high standard of intellectual attainment, providing a correct blending of theory and practice is maintained and students are not led to believe that academical knowledge is all sufficient. Such a possibility is not likely at Sheffield University under the able direction of Dr. J. H. Andrew, where it is proposed to inaugurate a course in foundry technology in its widest sense which will ultimately lead to the conferment of a degree.

The fact that Sheffield University has taken the matter up is fortunate for the industry, for the City has a tradition in the production of castings, particularly steel castings which makes its name familiar throughout the industrial world. Apart from this, however, the Metallurgical Department at this University is in a special position to supply such a training. It possesses the essential equipment and a competent technical staff. Already Mr. H. F. Coggon of Messrs. August's, Ltd., has offered additional equipment for the foundry, and we believe many firms supplying foundry equipment would be willing to co-operate with the University in a like manner.

Many subjects would naturally be included in the curriculum for such a course, and special consideration would need to be given to the subjects chosen and the time allocated to each. The success of this proposal depends on the extent of support it receives for the industry, and all foundrymen should co-operate and give such support as they are able towards the fulfilment of this project.

Relative Position of the U.S.S.R. in the World Production of Raw Materials.

THE Five Year Plan of the U.S.S.R. has done much to show how rich Russia is in her possession of natural resources. Before the war her possibilities in this connection were little known, and as the greater part of her vast territory was devoted to agricultural pursuits, her resources were little explored. It is not surprising, therefore, that the economic scheme instituted by the Soviet Government should have made such a remarkable change. It was soon recognised that an ample supply of raw materials was of vital importance to the success of the Plan, and considerable investigation and prospecting of geological and hydrological resources of the country led to many valuable discoveries which facilitated the rapid industrial development that has been effected. Rapid application of her resources has advanced the Union to one of the foremost positions in the share of the world's supply of minerals and water-power, and a glance at the following table will indicate the relative percentage of the resources of the U.S.S.R. to the world's supplies :—

	%
Copper	13·6
Lead	8·7
Zinc	13·2
Iron	57·0
Manganese	64·2
Potassium Salts	64·1
Phosphorites and Apatites	62·1
Coal	13·1
Oil	26·2
Water Power	29·3

From the above percentages it will be seen that in the case of iron and manganese ores, potassium salts, phosphorites and apatites, the resources of the U.S.S.R. are greater than the combined resources of the rest of the world. In regard to oil and water power, the Union possesses about one-third of the total world resources, while in coal and non-ferrous metals a supply sufficiently large is available to support a rapid development of the branches of industry depending upon them.

In addition to her increased supplies of water power and minerals the U.S.S.R. has made fundamental advancement by the erection of immense plants to develop her industries, and very great progress has been made. In this rapid industrial development it should not be overlooked that it has taken place under conditions of unparalleled depression in those countries that have long been industrialised. Some indication of her progress as a producing nation, in comparison with world production, is given in the following figures, from which it will be appreciated how great a change has been effected.

In 1928, for instance, the proportion of the U.S.S.R. in the volume of world production was 4·7%; in 1932, however, it had increased to 14·9%. As a result of this improvement the U.S.S.R. jumped from fifth position in 1928 to second position in 1932. In her output of both pig iron and steel she moved from fifth to second position during this period; in oil she advanced from third to second place; in coal from sixth to fourth; while in the output of machinery she advanced to second place from fourth. Further extension of these industries in the present year shows every indication of consolidating their position in world industrial production.

The first Five-Year Plan has brought great changes to the composition of Soviet industry, the greatest of these being the increased weight of the groups of plants engaged in the basic industries to the total volume of production. In 1913, for instance, the weight of these groups to the total volume of production was 41·8%, and in 1928, the eve of the Five-Year Plan, 44·5%, in 1932, however, it had jumped to 52·5%. To appreciate the significance of this fact one has only to realise that on the eve of the world crisis the weight of the output of means of production to the total volume of industrial production of such countries as the United States, Germany, and Great Britain was 55–60%, 45–50%, 35–40% respectively.

Continuous Casting of Steel Sections to Reduce Rolling

By B. Sheynin, A.M.I.Mech.E., M.I.S.Inst.

Asst. Professor of Technology, Moscow.

A method is suggested in this article whereby billets are cast direct with the object of curtailing the amount of rolling necessary for certain types of small ferrous sections. Economy is claimed to be the primary object.

ORDINARY commercial grades of steel are quite satisfactory for many purposes; for instance concrete reinforcements, certain classes of wire rod, and small sections, etc. For these purposes the quality of steel is not expected to be particularly high, and their production offers opportunities for a considerable curtailment in the ordinary process in order to effect economy. The usual process of making steel irrespective of its final size and shape and its application, is well known. It consists in casting an ingot varying in size, but with the object of breaking it down in a cogging or roughing mill and subsequently rolling it to the required size and shape in a finishing mill. That process is essentially the same whether the manufacture is ¼ in. wire rod or 5 in. angle iron. Obviously, the smaller the size of the final product the greater the number of operations that will be necessary on the ingot; many of these break up the structure of the steel and increase its quality, but the majority are required primarily to reduce the ingot nearer to the desired size or shape.

Is it really necessary for all these wasteful operations of casting, breaking down, and a final rolling for all the small relatively unimportant sections? It seems that, for certain sizes, a simple and straightforward method of steel manufacture could be developed on more economical lines.

It is, of course, well known that the casting of metal pigs, by means of an uninterrupted stream of metal into a continuous travelling line of moulds of given shape, has reached a high degree of perfection. The technique in manufacture by this process has made substantial progress in pig iron and non-ferrous metals manufacture, and the experience obtained shows that there are apparently no unsurmountable difficulties in the way of casting a pig of continuous length should it be necessary. All that is needed is a mould placed longitudinally on the machine and operated at a speed approximately equal to the speed of the hot metal stream so that no overflow occurs. Such a machine would need to be slightly inclined towards the pouring end, and it should not offer difficulties since there is no difference in casting a long bar of cast iron from casting a bar of steel. The essential features of a casting process of this character may be briefly summarised as follows:—

(*a*) Steel of any chemical composition and fluid enough to run easily can be cast in this way.

(*b*) The speed of the stream of molten metal would not be constant, and therefore pouring under a variable head of metal could not be employed. This would necessitate some special apparatus through which the steel could be poured.

It is reasonable to assume that the ladle could be dispensed with altogether. The hot metal tapped from the open-hearth furnace should be directed into an open refractory-lined runner, the cross-section dimensions of which should suit production. The end of the spout should be closed by means of a gate, leaving an opening in the lower part of the gate for the metal to run out on to the conveyer. At different places in the runner refractory lattices of a suitable design should be placed which would serve as collectors of impurities in the steel, and with dissolved gases compel them to rise to the surface.

(*c*) Undoubtedly the most important part of such an installation would be the conveyer mould or troughing; the design of such a conveyer would tax the experience and knowledge of the conveyer experts. A decision would need to be made, for instance, regarding the most suitable heat-resisting material and the selection of a refractory for its covering capable of withstanding changes of temperature during pouring and cooling of the molten metal. In addition, it would be necessary to take into consideration a reasonable amount of shock and vibration associated, even with a smooth-running conveyer. The main difficulties, however, would be in arranging for the high speed of the conveyer and in obtaining metal-proof connections between adjacent sections of the endless conveyer.

If it is assumed that the teeming of the metal into the conveyer would be something like 2 tons of metal per minute, and the size of cast bar 3 in. square, the length of the bar cast would be about 170 ft. per minute. Obviously, only at such relatively high speeds would the conveyer be able to accept the poured metal and to freeze it into the given size of bar, as a slower speed would result in an overflow of metal and in piling it up when cooling. It is certainly possible to cast a bar to any simple profile of larger dimensions, but such a bar would not give the whole benefit accruing from the replacement of the cast ingot method.

The proper fit of the conveyer sections is absolutely essential, as otherwise the metal would flow into the open joints, causing damage to the conveyer and resulting in a bar covered with heavy fins.

(*d*) The time of cooling the stream of hot metal, 3 in. × 3 in. square on the conveyer down to a rolling temperature would depend upon the type of conveyer. A refractory lining will tend to delay the cooling, while a metal conveyer will cool the metal in a relatively short time, especially if the conveyer is sprayed from underneath by means of jets of water. It can be reasonably assumed that the time of freezing would vary from 1 to 1½ mins. according to the procedure adopted, and the conveyer would be of necessity about 200 ft. in length.

(*e*) The hot bar leaving the conveyer should be arranged to pass over a few short live rolls with side guides. When set with their upper surfaces a little above the bottom of the conveyer the rolls would tend to lift the bar from the conveyer and transfer it to the flying shears for cutting into suitable lengths.

(*f*) It is unlikely that the bar would be entirely free from dissolved gases, and its surface would probably be covered with small gas cavities. It would be advisable, therefore, to pass the bar through a pair of rolls which would slightly reduce the bar in size just sufficiently to bring it to the right shape, and at the same time close all the spongy sections which may be present, and thus avoid the formation of blisters. A slight tension behind the rolls will prevent the formation of loops and will be beneficial to the bar.

After giving this process much consideration, it seems that there is nothing to prevent the construction of a relatively small plant capable of producing 3 in. × 3 in. bars at a speed of 100 tons per hour, which would amply cover all the requirements in small sections of any large steel plant, particularly for the type of commercial steel referred to.

Cheaper Steel Developments

Progress at the Irlam Works of The Lancashire Steel Corporation Ltd.

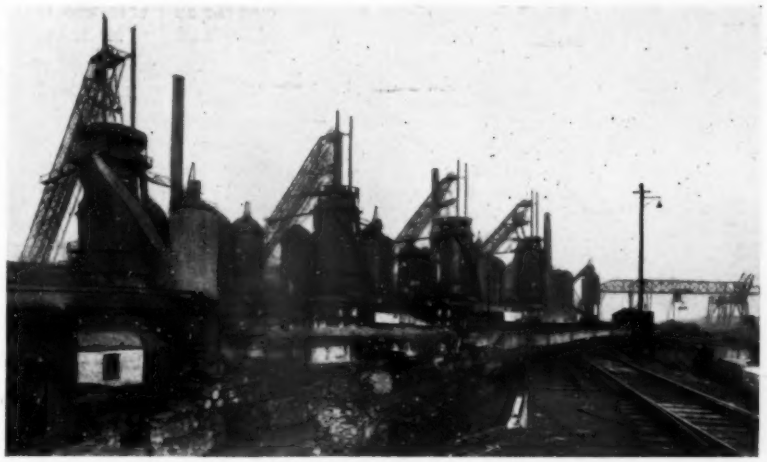
Courage, foresight and technical ability of a high order are shown in the reorganisation that has been effected at these works. The developments are far-reaching, and have been carried out to suit the peculiar needs of the British iron and steel industry. The most important feature in the progress achieved is the rapidity of changing the equipment and technique to meet market conditions.

THIS Corporation was incorporated in 1930 to acquire the iron and steel assets of the Pearson and Knowles Coal and Iron Co., Ltd., Partington Steel and Iron Co., Ltd., and the Wigan Coal and Iron Co., Ltd.

The coal assets of the Pearson and Knowles Coal and Iron Co., Ltd., and the Wigan Coal and Iron Co. Ltd., together with those of the Moss Hall Coal Co., Ltd., and the Wigan Junction Colliery Co., Ltd., were transferred to the Wigan Coal Corporation, Ltd., in which the Lancashire Steel Corporation is largely interested. In addition, this Corporation now owns the entire share capital of Rylands Brothers, Ltd., and the Whitecross Co., Ltd., both large manufacturers of steel wire, as well as the Pearson and Knowles Engineering Co., Ltd.

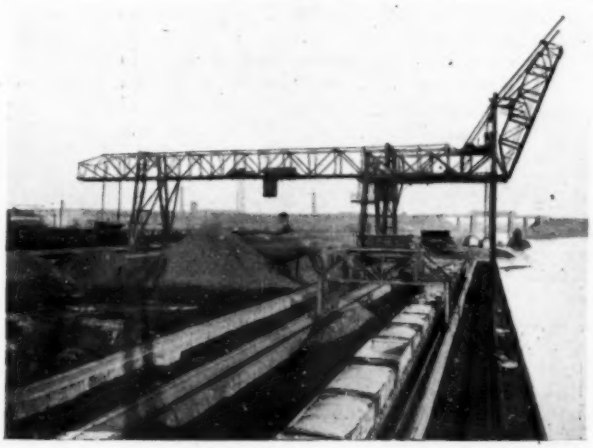
The coke ovens, blast-furnaces, and steelworks are located at Irlam, and were formerly the works of Partington Steel and Iron Co., Ltd. The merchant mills, iron forges, wire and engineering works are at Warrington, while the coal properties are in the Wigan area of Lancashire, together with an important colliery unit located near Worksop.

The scheme of development primarily affected the works at Irlam, which are situated on the Manchester Ship Canal, and cover an area of 209 acres. Served by the Cheshire Lines, L.M. and S., and G. W. railways, these works are now in a very favourable position with regard to both inland and sea-borne traffic. An ample coal supply is available locally, and the coke ovens, blast-furnaces, open-hearth plant, and rolling mills installed manufacture steel from the raw materials. Efficient utilisation of the fuel, made available and required in the various processes of manufacture, formed an important part of the scheme.



Blast furnace plant as modernised.

View along wharf showing distributors over ore bunker and "Goliath" crane spanning dump.



The products consist of all sizes of constructional sections, rails, fishplates, and semi-finished materials, down to the smallest diameter of rolled wire rod. This, however, has only been achieved as a result of the development, which has been in progress over three years, and the installation of much plant and equipment. This has been carried out under the direct supervision of Messrs. H. A. Brassert and Co., Ltd., of London, the well-known consulting engineers. In many respects these works present an outstanding example of efficiency. It will, therefore, be of interest to discuss briefly the comprehensive development made at these works, and thus indicate the extent of the contribution they provide towards an economically efficient British iron and steel industry.

The handling of raw materials has an important influence on the cost at which steel can be manufactured, and this operation was carefully considered in an effort to reduce transport to a minimum. Previously all sea-borne materials were carried to Manchester and returned to the works by rail. This offered scope for considerable saving in transport, and it was decided to institute new work comprising the installation of a modern unloading dock located on the Manchester Ship Canal where the existing plant of the Partington Iron and Steel Co. was built. This modern unloading dock is 600 ft. in length, and is capable of accommodating the largest vessels using the Manchester Ship Canal. It is equipped with two high-speed unloaders, and a modern ore bridge, with a storage yard for ore and coal. The unloading cranes, which were constructed by Pearson and Knowles Coal and Iron Co., Ltd., to Demag designs, unload the raw materials direct from the ships; each has an unloading capacity of 125 tons per hour. All the ore is weighed in automatic weighers, and then deposited in a storage trough running the full length of the wharf. From this trough the ore is picked up by the traveller on the ore bridge, which has a capacity of 250 tons per hour. The ore is then deposited in the main storage yard, which provides accommodation for more than 100,000 tons, or can be placed direct into wagons for crushing.

A feature distinguishing this ore handling equipment is the way of adapting the electric equipment to the requirements of efficient and safe high-speed operation. The layout and all details have been developed in close co-operation between the crane builders and A.E.G. Electric Co., Ltd., the makers of the electric equipment. The two 10-ton bridges are operated with motors having outputs of 42 h.p. for bridge travelling, 60 h.p. for closing, 50 h.p. for crab travelling, 136 h.p. for lifting, and 27 h.p. for luffing-in.

Automatic contactor control gear is employed throughout, and in designing and arranging the master controllers special care has been taken to reduce the number of operations and the effort to be applied by the operator as far as possible. For this reason the controllers for the closing and lifting circuits are built together into a single unit, worked by a single lever. In the lifting circuits current in either direction can be applied when lowering; this enables the operator to use very high lowering speeds and also to stop the lowering movement without straining the mechanical brake, and with great precision.

In addition, there is a bunker truck, driven by a 40-h.p. travelling motor, and with two 7-h.p. chute opening motors, and an ore distributor driven by a motor of 46 h.p., The electrical accessories include motor-driven brakes, lifters, and all usual safety devices. The whole equipment is claimed to be unique as regards the ease with which heavy loads are handled at high speed.

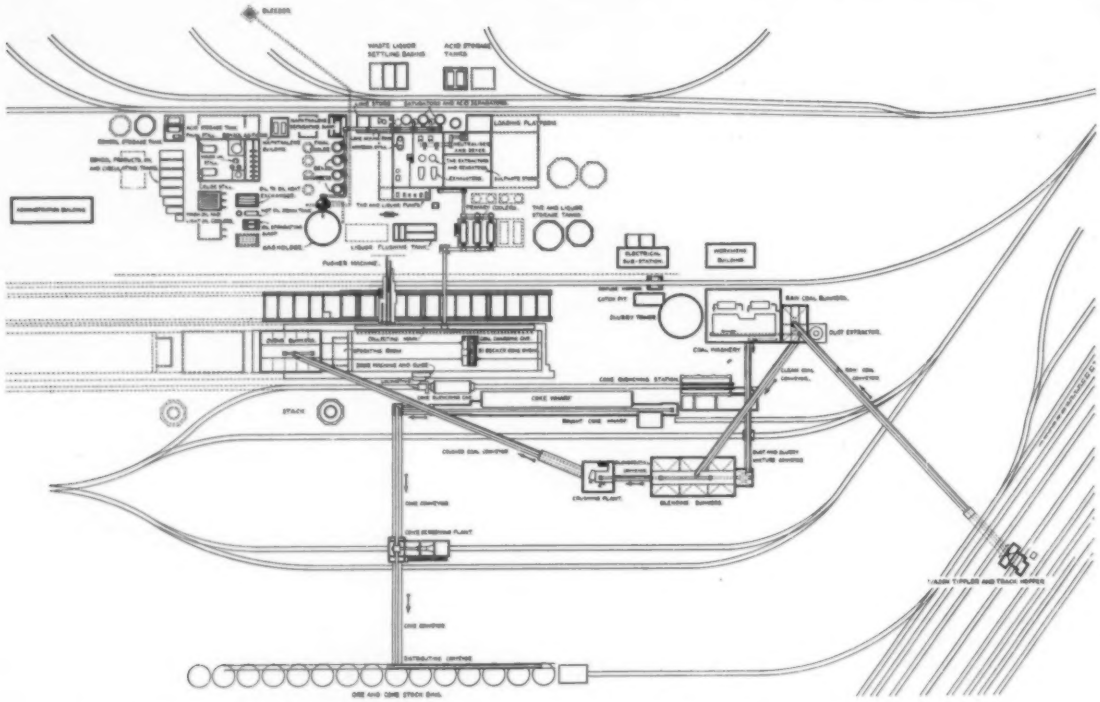
The crushing plant, built by Edgar Allen and Co., Ltd., has a capacity of up to 250 tons per hour, and crushes the ore down to 4/5 ins. size. From the crushing plant the ore is conveyed by a 30-in. belt to a screen, which separates the fines from the lumps, and is then conveyed to the blast-furnace ore bins by means of a 24-in. conveyor. In addition, a shuttle conveyor has also been installed over the blast furnace bins for the transference of coke from the coke oven plant. This conveying machinery was designed and installed by the Mitchell Conveyor and Transporter Co., Ltd. The plant is adequately housed, and a special wagon hoist and tippler is installed to supply the raw material direct to the crusher.

Coke Oven and Coal-washing Plants.

The installation of a modern coke oven plant with coal washery and by-product plant forms an important feature of these developments. This plant, which was referred to in detail in our May issue, consists of a battery of 51 Becker ovens, designed and built by the Woodhall Duckham Vertical Retort and Oven Construction Co., Ltd., to produce 5,000 tons of coke per week. These are so arranged between the raw materials handling plant and the blast furnaces that no hand labour is required from the mechanical tipping of the slack wagons to the delivery of the coke to the blast furnaces. They are arranged in a single battery with the coal storage at one end to allow for a future extension when this becomes necessary.

Each oven is 40 ft. 8 in. long between doors, 13 ft. high, and has an average width of 16 in. With a holding capacity of 651 cub. ft., each battery has a total production capacity of 5,000 tons of coke per week. The ovens are designed so that they can be heated with either coke-oven or blast-furnace gas. The reversing machine, which operates the reversing valves for the air and gas passing through the regenerators, is controlled electrically, and failure in the operation of the mechanism at a predetermined time is indicated by a steam siren.

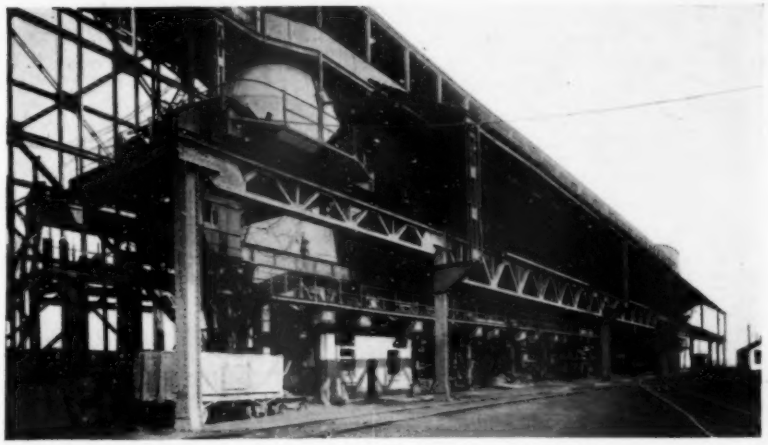
The combined by-product and coal washery plant is designed to handle 175 tons of coal per hour of up to 1-in. raw coal. The raw coal extracted from either of two hoppers, each having a capacity of 250 tons, which are filled by tippling and conveyor mechanism, is fed into a "Birtley" de-dusting plant which extracts the major portion of the fine dust below 1/60 in. in bag filters. The bag filters are located over dust conveyors so that the extracted dust can be conveyed to be mixed with the de-watered slurry. The de-dusted coal subsequently passes into a "Baum" washery, in which the washing boxes are provided with "Norton Hardy" automatic shale extractor gates. From the washery the clean washed coal is conveyed by a belt conveyor to blending hoppers, and from the latter through grinding machines to the oven storage bunker, which has accommodation for 2,000 tons of coal.



General layout of "Becker" coke-oven installation, coal washing, blending and handling plant, coke-handling and screening plant, and by-product plant.

Blast-furnace Plant.

The blast furnace plant has been remodelled. This consists of four blast furnaces and there is provision for a fifth. These produce basic, foundry, and special irons. One furnace with its own gas-cleaning plant is especially arranged for the manufacture of ferro-manganese. The whole blast furnace plant is equipped with bunkers, inclined hoists, and mechanical charging apparatus, all hand labour in connection with charging being eliminated. The main additions have been in the reconstruction of four hot blast stoves, in which have been installed the latest type of Brassert's checkers and fillings. The blast furnaces themselves have been relined and consist of two furnaces each capable of producing 2,000 tons of basic iron per week, together with a blast furnace for producing up to 600 tons of ferro-manganese per week. The fourth furnace is reserved for making high-grade foundry iron.



Blast-furnace ore bins and sintering plant.

The hot blast stoves have been fitted with modern automatic gas burners each capable of burning up to 10,000 cub. ft. of blast furnace gas per minute according to the requirements of the furnaces. These burners are fitted with blowing fans and will ultimately be operated with automatic combustion control apparatus.

The large increase which has been brought about in the heating surface of the hot blast stoves, coupled with efficient hot blast stove burners, will result in increased economy of blast furnace gas, leaving a larger surplus of gas for distribution in other parts of the plant. In addition to the new burners, new water-cooled hot blast valves and cold blast valves have been installed on the stoves.

A further addition to the reconstruction of the blast furnace plant has been the installation of a modern gas cleaning plant for cleaning the gas down to a fine degree of cleanliness. This plant consists of a main gas-cleaning unit, including two pre-cooling towers, two disintegrators and eliminators of Brassert design, capable of dealing with up to 100,000 cub. ft. of gas per minute, and cleaning this volume down to 0.01 grammes per cub. metre, together with a second plant to deal with the gas from the ferro-manganese furnace.

The main gas-cleaning plant and the ferro-manganese cleaning plant are inter-connected so that either one, two, or three disintegrators can operate, according to the demand of the load. The isolation of the ferro-manganese gas-cleaning plant is accomplished by means of a specially designed goggle valve which operates successfully under conditions of hot, wet, or dirty gas.

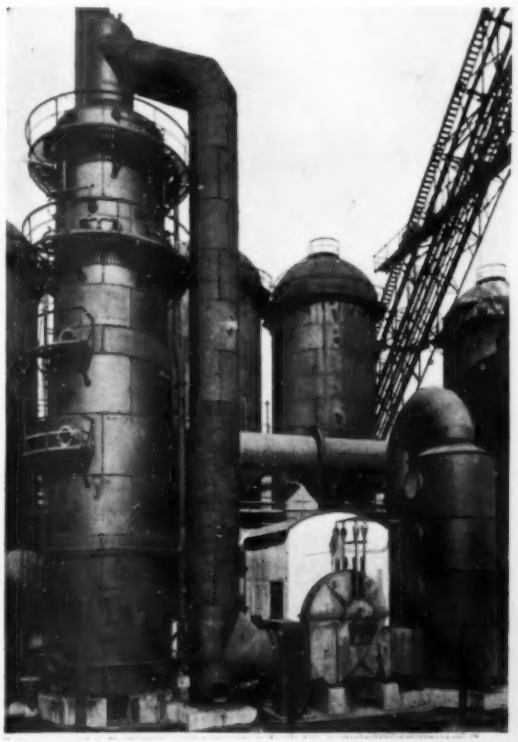
Power Plant.

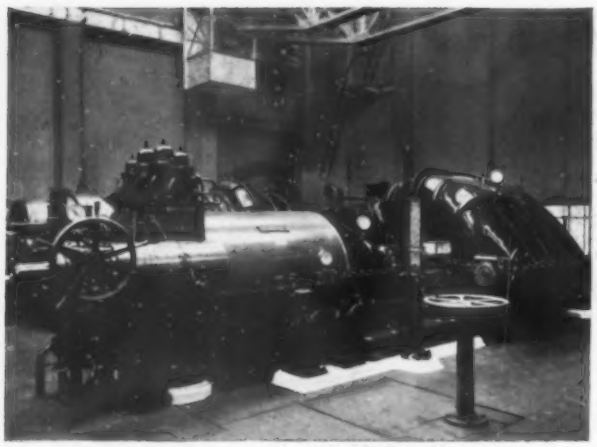
The power plant is equipped with both blast-furnace gas engines and steam engines, the total installed capacity being 10,000 k.w. The blowing plant consists of both gas-engine-driven and steam turbo-blowers housed in the same building as the power plant. The installation in the power house comprises four 1,500 b.h.p. National vertical tandem gas engines driving Bruce Peebles D.C. generators. These engines operate on blast-furnace gas and work on the four-cycle system. Cylinders are placed two in tandem over each crank, which, by firing alternately, give a working stroke on every downward stroke and a compression stroke in either the top or bottom cylinders on the upward movement. The space between the top piston and the intermediate cover is utilised as a buffer cylinder in which compression of the air takes place on every down-stroke and expansion on the up-stroke. This cushioning effect, together with the number of cranks, gives an even turning effort. Each engine is governed by means of a throttle valve controlled by centrifugal governor. The valve, throttling both gas and air, can, if desired, be arranged to change the mixture with variation of load.

Of the blowing engines three consist of 1,500 b.h.p. National vertical tandem gas engines driving National reciprocating blowers. These are of the four-crank type designed to deliver 24,000 cub. ft. of free air per minute against a pressure of 12 lb. per sq. in., but the blower can deliver air against a pressure of 16 lb. per sq. in. when required. Special arrangements are made by means of valves in the delivery pipe so that if higher pressures are required than that for which the gas engine is capable of producing when the full volume of air is delivered, one or two blower cylinders can be cut out and the air from these made to return to the suction pipes. For the purpose of starting the engine, and also when no air is required, all the cylinders can be made to deliver the air back again into the suction pipe. These modifications are effected by means of a single handwheel accessible from the floor level.

A new turbo-blower has been installed, which is the

Gas cleaning plant for No. 3 (Ferro-manganese) blast furnace.





Brown-Boveri turbo-blower.

largest of the units, and makes the capacity of the installation 225,000 cub. ft. per min. This turbo-blower is of Brown-Boveri design. The turbine is of the single-cylinder combined impulse and reaction type direct coupled to the blower, which is of the single-cylinder three-stage pattern fitted with movable diffusers on the last two stages to permit of the operation of the blower set at very low volumes without pumping. The condensing plant is of the jet type and was supplied by Hick, Hargreaves and Co., Ltd.

The steam turbine is designed for live steam at a pressure of 150 lb./sq. in. gauge, superheated to 456° F., and for exhausting against a vacuum at the turbine exhaust flange of 28·25″ Hg. (Bar. 30″). At the moment, the turbine is fitted with steam nozzles specially designed for the present normal duty of the blower set—viz., 37,500 cu. ft. of air per minute with a delivery pressure varying from 12 to 20 lb./sq. in. gauge.

A further set of steam nozzles has been supplied for the turbine and, at a later date, when these are fitted, the turbo-blower set will be suitable for a normal duty of 50,000 cu. ft. of air per minute with a delivery pressure of 15 lb./sq. in. gauge, and under these final conditions it is actually capable of dealing with up to 60,000 cu. ft. of air per minute with a delivery pressure of 12 to 15 lb./sq. in. gauge and even 52,000 cu. ft. of air per minute with a delivery pressure of 20 lb./sq. in. gauge.

An automatic blow-off valve is provided for use when starting up the plant, the control system of which is interlinked with that of the movable diffusers, so that the blow-off valve would operate only when excessively low air volumes have to be dealt with. The turbo-blower is also fitted with " Brown-Boveri " regulation gear for ensuring a constant volume of air passing through the blower set, and it is possible to ensure a constant weight of air being delivered to the blast furnace.

Steel Plant.

The open hearth plant consists of furnaces with capacities from 50 to 90 tons, and a 300-ton mixer is installed for molten metal from the blast furnaces. The plant is arranged for the manufacture of special steels as well as the usual qualities of merchant steels. The reconstruction of the steel plant, up to the present, consists of the rehabilitation of four 50-ton open hearth furnace units together with two newly-constructed 90-ton Venture furnaces, and the third is in process of re-building.

Tapping a 90-ton open-hearth steel furnace.

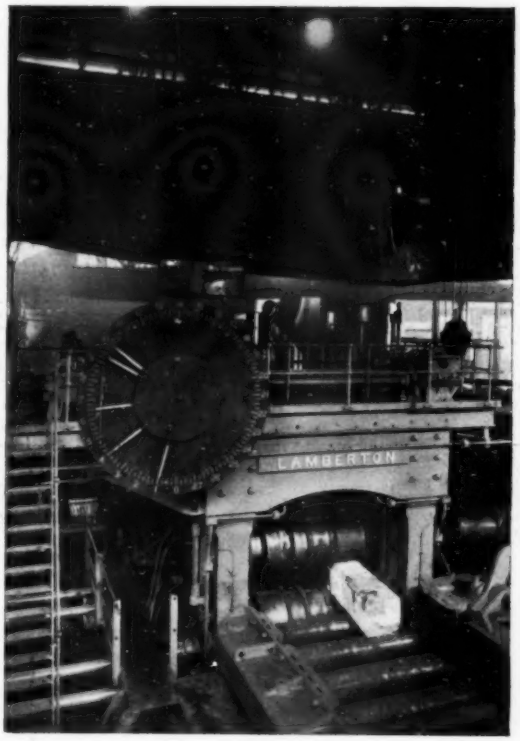
Open-hearth steel plant. Casting into moulds on bogies.

This battery of open hearth furnaces is capable of producing from 300,000 to 350,000 tons per annum, and constitutes one of the most modern melting shops in the country. The furnaces are designed with specially constructed water-cooled parts, together with the modern cooling of the block end brickwork and Blaw-Knox water-cooled valve equipment. In addition, these units have modern patented checkering, sloping backwalls, and electrically operated doors and reversing valves. Both the large and the small furnaces are designed to operate with producer-gas or with mixed blast-furnace gas and coke-oven gas.

In addition to a number of charging machines, a new electric overhead slewing open hearth charging machine has been installed by Babcock and Wilcox, Ltd. This machine is arranged to handle a gross load of four tons on the charging bar. In addition, it is equipped with a 15-ton auxiliary crab, the cross girders being of the three-girder design, providing separate tracks for the main trolley and the auxiliary crab. Arranged to run on rails at 51 ft. 6 in. span, the speeds of the various motions give six complete strokes per minute when bar hoisting :—250 ft. per minute main cross traversing, ten revolutions per minute slewing, twelve revolutions per minute bar turning, 30 ft. per minute auxiliary hoisting, 150 ft. per minute auxiliary

cross traversing, and 400 ft. per minute longitudinal travelling. The motors are of the steelworks type, whilst the control gear for all motions is of the contractor type, the auxiliary hoisting control gear being provided with slow speeds and dynamic braking in order to ensure accurate handling of the load.

On the casting side two new 125-ton tapping cranes have been installed and provision made for bogie casting. These were installed by Wellman Smith Owen Engineering Corporation, Ltd., each being equipped with an auxiliary hoist for dealing with loads up to 25 tons. The motors which operate on direct current at 500 volts, are Metropolitan Vickers Electrical Co.'s totally enclosed, series wound, interpole reversing type. Each motion is operated by means of a separate contactor panel and master controller of Allen West and Co.'s manufacture.



New cogging mill with capacity of 120 tons per hour.

Five new hot metal ladles have been installed by Babcock and Wilcox. Each is complete with two sets of stopping gear. The ladles taper from 10 ft. to 9 ft. 1½ in. inside diameter of shell, and are 9 ft. 7 in. deep. From these ladles the metal is cast into ingot moulds mounted on bogies in sets of four. For stripping ingots, bogie cast, a new 100-ton stripper crane has been installed to carry 12 tons, and is capable of exerting 100 tons when stripping. All unnecessary handling and transportation are eliminated.

Rolling Mills.

To meet the increased demand production of the open hearth furnace plant, it was necessary to improve the output of the cogging mill, and for these new conditions a modern electrically driven 40-in. reversing cogging mill has been installed by Lamberton and Co., Ltd. This mill has a capacity of 100 tons per hour, and deals with the ingots down to blooms for use in the reversing finishing mill and the three-high mill, while the three-high mill in turn provides billets for the rod mill.

A new modern wire-rod rolling mill is nearing completion. The mill is supplied by Messrs. Davy Brothers, Ltd., of Sheffield, to the latest design of The Morgan Construction

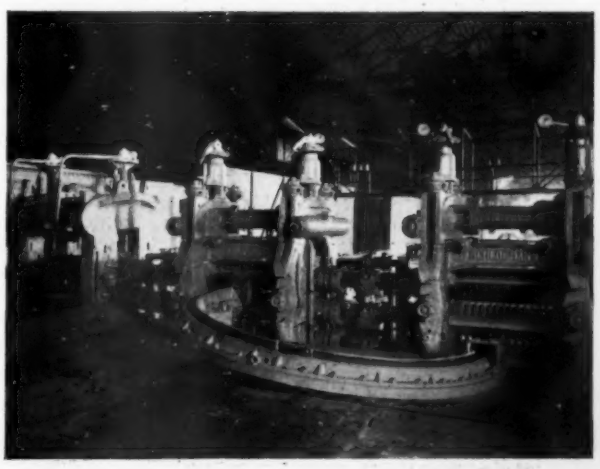
18-in. Mill-roughing rolls (first pass).

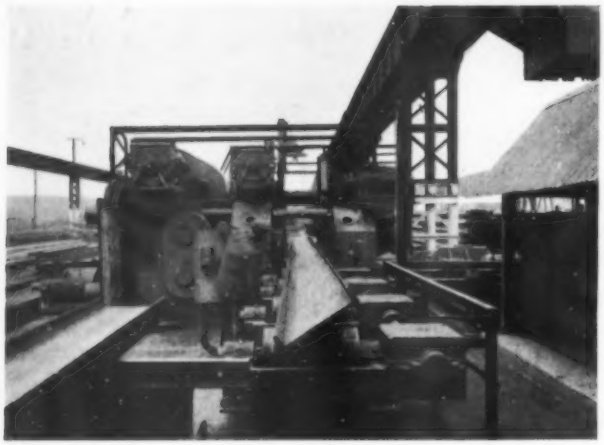
Co., Ltd., for an output of up to 3,000 tons per week. The electrical equipment is by the English Electric Co., Ltd., and contains many special features which give great flexibility and accurate control and enable the mill to cover a wide range of rod products. An important feature of this rolling mill is the latest Morgan design of heating furnace incorporating metal recuperators.

The high output of the new cogging mill has necessitated changes in the 32-in. finishing mill, chiefly on the lines of providing quick roll changing, and two finishing stands built by Duncan Stewart and Co. were installed. Each roll housing weighs about 8½ tons and is open topped with caps pulled down on taper seats by swing bolts. The two housings of each stand are tied together top and bottom. The stretchers are exceptionally rigid. By thus coupling the housing together, while keeping the caps separate, the transmission of roll and thrust loads through the cap joints is avoided. Both top and bottom roll chocks are adjustable by 9 in. diameter 1¼ in. pitch screws, hand operated through worm gears. The top rolls are balanced by pairs of hydraulic rams acting through beams and push rods, the push rods being lifted out with the housings, leaving the cylinders and beams behind.

The complete operation of roll changing has been carried out in the short time of 35 minutes. When doing this the only operations necessary are to uncouple the spindles, slacken the swing bolt nuts, swing back the bolts, and engage hooks cast on the top cross girders with the special lifting tackle provided. The whole stand weighing about 50 tons complete is then lifted out. One or other of the two change stands also supplied, having previously been set

18-in. Mill-finishing rolls with repeater.





Joist straightening machine showing reversing of 18" × 6" joist.

up on a separate erecting bed, is then put in place by a reversal of the above procedure.

In this mill a new 60-ton electric traveller crane has been installed to facilitate the rapid changing of rolls. The crane was designed and built by Broadbent and Sons, Ltd. This crane is equipped with an auxiliary hoist, the whole installation being of the modern type.

On the cooling banks a number of improvements have been made, including the installation of a modern section straightener and new machines for turning rounds. Changes have also been made between the cogging mill and the finishing rolls, and skid gear has been installed to carry the hot blooms from the cogging rolls to a new reheating furnace on the 18-in. mill.

New additions have also been made to the existing 20-in. merchant mill by providing a modern reheating furnace for blooms. This reheating furnace which was designed and constructed by The Wellman Smith Owen Engineering Corporation, Ltd., has many special features. The hearth is 58 ft. long and 14 ft. wide, with an area giving 812 sq. ft. heating surface. Charged with 6 in. × 6 in. × 12 in. blooms it has a capacity of 56 lb. per sq. ft. per hour, or a normal output of 20 tons per hour. There are two firing zones, one on the top and the other beneath the blooms. The furnace is of the end discharge type, the blooms being pushed down the furnace by an electric pusher. It is automatically discharged, the blooms being delivered to the mill roller train. The air is supplied under pressure through recuperators, and the furnace has been designed for firing by producer-gas, coke-oven gas, or a mixture of blast-furnace and coke-oven gas. The ports are of the "Wellman-Soward" patent design, while the roof is of the flat suspended type.

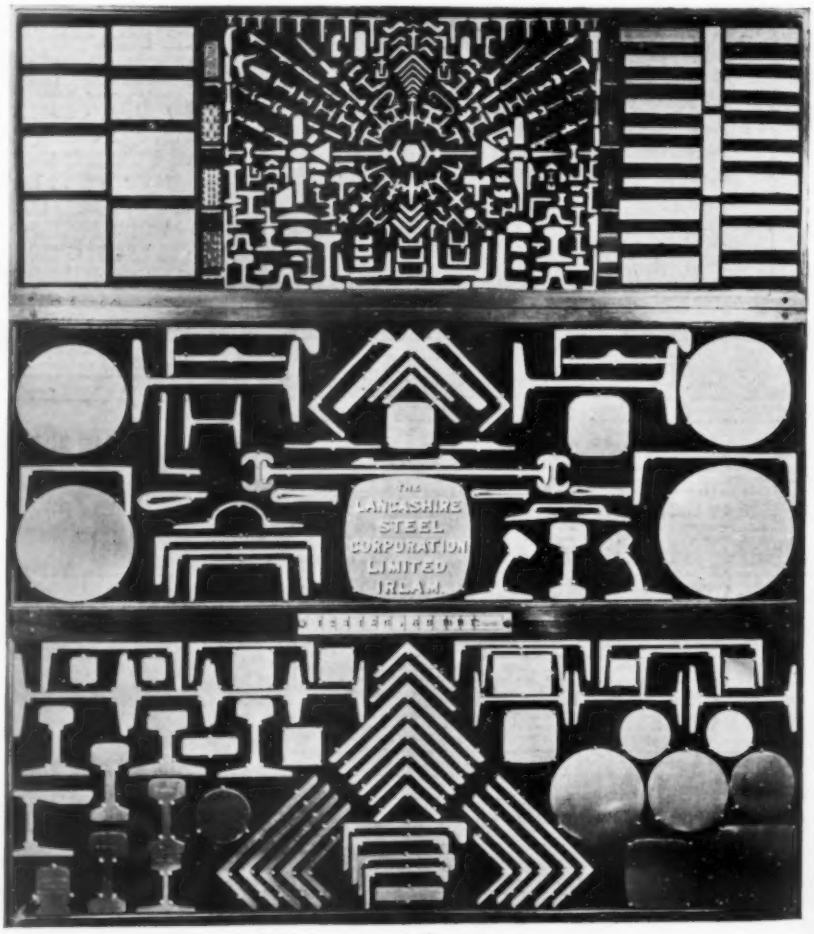
The Schloemann 20-in. mill has been remodelled. To meet this new output new hot and cold banks have been installed on this mill.

Much auxiliary equipment has been installed, particularly in regard to increased facilities for transporting in the mills buildings necessitated by the general speeding up in production. In the rod mill building, for instance, two 10-ton five-motor electric traveller cranes, with a span of 83 ft., installed by Babcock and Wilcox. They are provided with a main 10-ton hoist and two 1-ton auxiliary hoists which are normally used with a hairpin hook for the purpose of handling the rods.

A necessary side of the iron and steel plant to-day lies in adequate provision being made for by-products, not only in regard to the system incorporated in coke-oven plant, but in the full utilisation of slag for road-making purposes, and it was therefore decided to install a new tar macadam plant, with a crushing capacity of 500 tons of slag per day. In addition to the crushing of slag for tar macadam, this plant also provides fines for the manufacture of flags and kerbs, together with other artificial stone products.

British iron and steel manufacturers are realising that the order is changing, and appreciate the need for modern methods of manufacture and the most suitable equipment, so that greater operating efficiency can be effected with a reduction in the cost of production. Many manufacturers have displayed the courage of pioneers and have overcome tremendous difficulties in giving a lead to the British iron and steel industry towards a position in the new order commensurate with its importance. There is much to be done before the position of the industry can be regarded with optimism, but these developments effected at the Irlam Works of the Lancashire Steel Corporation constitute an important step towards its fulfilment.

Some sectional examples showing the wide range of products manufactured at the Irlam Works.



Relating the Chemical Composition to the Micro-structure of a Complex Brass

By Wesley Lambert, C.B.E.

Data are given in this article by which the percentage micro-structure of a known composition can be determined, within close limits, in the absence of a complementary micro-photograph of a particular alloy.

IT will be readily conceded that it is often very desirable to have a knowledge of the micro-structure of a complex brass. Sometimes for instance, when studying the analyses of a series of manganese bronzes, one has occasion to regret the absence of a complementary photo-micrograph of a particular alloy. It is not generally recognised, however, that one can determine, with close approximation, the percentage micro-structure of a complex brass of known composition, without the necessity of recourse to a microscopical examination.

Metallurgists are indebted to M. Guillet, the distinguished French metallurgist, for publishing data whereby such determinations can be made, and M. Guillet's "coefficients," arrived at as the result of the laboratory examination of numerous specially prepared alloys, are, with slight modifications, in daily use at the present time. M. Guillet found that in a complex brass, each of the constituent metals additional to the basis metals, copper and zinc, may be related to either one or the other of the basis metals by using suitable coefficients. The percentage figures for the "fictitious copper" and "fictitious zinc" of the binary "alloy," thus arrived at, can be applied in a method of arithmetical calculation to determine the approximate percentage content of the micro-constituents of any such alloy.

Table I. gives M. Guillet's "coefficients" for the respective elements named :—

TABLE I.

Element.	Coefficient of	
	Zinc Equivalent. Zinc = 1.	Copper Equivalent. Copper = 1.
Aluminium	6·0	—
Manganese	0·5	—
Iron	0·9	—
Tin	2·0	—
Silicon	10·0	—
Lead	1·0	—
Nickel	—	1·2

A glance at the above table will suffice to show that both aluminium and silicon have a high "zinc equivalent" value, or in other words that each of these two elements, when added to a brass, exercise on the alloy a much more pronounced modifying effect, per unit addition, than would the addition of a like amount of, say, either manganese or iron.

Further, we are indebted also to M. Guillet for the publication of a table (Table II.) setting out the limits of the zinc content of the copper-zinc series of alloys, grouped according to their respective micro-structures.

Of the groups enumerated in Table II., only the first three relate to brasses of commercial utility; the introduction of the brittle constituent gamma in the fourth group rendering the alloys of that group of little or no industrial value. The data given in the table have been, in a few instances, slightly modified as the result of the researches of investigators subsequent to the publication by M. Guillet. However, the figures given in the table are

TABLE II.

COPPER-ZINC ALLOYS.

Group.	Micro-structure.	Zinc Content %.
I.	Solution (alpha) α	0 > Zn < 36
II.	Sol : (alpha) α + Sol : (beta) β ..	36 > Zn < 46·5
III.	Solution (beta) β	46·5 > Zn < 49
IV.	Sol : (beta) β + Sol : (gamma) γ..	49 > Zn < 60
V.	Solution (gamma) γ	60 > Zn < 69
VI.	Sol : (gamma) γ Sol : (epsilon) ϵ..	69 > Zn < 81
VII.	Solution (epsilon) ϵ	81 > Zn < 87
VIII.	Sol : (epsilon) ϵ + Sol : (eta) η ..	87 > Zn < 97·5
IX.	Solution (eta) η	97·5 > Zn < 100

those in daily use by the writer, and, for the purpose in view, may be accepted.

Reference to Table II. serves to show that in any series of copper-zinc alloys in which no alloy has a zinc content exceeding 36·0%, the micro-structure of any alloy of this series will be of the homogeneous, wholly-alpha phase; brasses having a zinc content between 36·0 and 46·5% will be found to have a duplex structure, both the alpha and the beta micro-constituents appearing together in one and the same alloy; whereas alloys having a zinc content between the limits of 46·5 and 49·0% will have a homogeneous all-beta structure. These findings are based on the assumption that all alloys are in a state of equilibrium or have been, at least, thoroughly annealed.

With a knowledge both of Guillet's "coefficients" and of the maximum and minimum limiting figures of the zinc content for each of the first three groups of alloys enumerated in Table II., one can proceed to make a determination of the percentage micro-structure of any complex brass, containing the elements specified, and coming within the industrial utility range of alloys, of which the percentage chemical composition is disclosed.

The writer submits the following example of such a determination :—

EXAMPLE.

"Copper."		Copper Equivalent.		Chemical Composition of the Alloy.			Zinc Equivalent.		"Zinc."
—	..	—	..	Zinc	40·0%	×	1·0	=	40·0
—	..	—	..	Aluminium	0·3%	×	6·0	=	1·8
—	..	—	..	Manganese	0·3%	×	0·5	=	0·15
—	..	—	..	Iron	1·0%	×	0·9	=	0·9
—	..	—	..	Tin	1·1%	×	2·0	=	2·2
—	..	—	..	Silicon	0·1%	×	10·0	=	1·0
—	..	—	..	Lead	0·2%	×	1·0	=	0·2
1·92	=	1·2	×	Nickel	1·6%		—		—
55·40	=	1·0	×	Copper ...	55·4%		—		—
57·32					100·0				46·25

		%
"Copper"	57·32 =	55·34
"Zinc"	46·25 =	44·66
	103·57	100·00

[Reference to Table II. will suffice to show that a simple conversion formula for determining the percentage content of the alpha constituent in a brass of known copper and zinc content may be written thus :]

Alpha content % = 465 – 10 (Zn%)

Therefore in the present example :

Alpha % = 465 – 446·6

= 18·4

And the estimated approximate percentage amounts of the alpha and beta micro-constituents of an alloy of the chemical composition cited above is found to be—

	%
Alpha	18·4
Beta	81·6
	100·0

The foregoing example shows the "lay out" recommended, and it will be seen that each of the metals constituting the alloy when multiplied by its own particular coefficient has then a "fictitious copper" or "fictitious zinc" value, as may happen. If then, the percentage amount of the latter is ascertained, it becomes a simple matter by making use of Table II. to arrive at the percentage micro-structure of the alloy. The figures 36·0—46·5% represent the minimum and maximum zinc content, respectively, of the series of alloys having a duplex structure, composed of the alpha and beta micro-constituents. It follows that, in the example chosen, in which the percentage "zinc" content is found to be 44·66, the micro-structure of this particular alloy will be of a duplex character, and the percentage amount of the one constituent having been determined, the amount of the second or complementary constituent is readily deduced. Had the "zinc" been 36·0% or under, the micro-structure would be of the homogeneous alpha phase, whereas had it been of anything between 46·5 and 49·0%, the structure would have been found to be of the wholly-beta phase.

A determination of the percentage "fictitious zinc" in a complex brass is often very instructive, as affording an indication of border-line micro-structures.

Some allowance, based on special knowledge, has occasionally to be made in the case of an alloy carrying a heavy percentage of aluminium, one effect of this metal being to extend the narrow limiting range governing the alloys of the Group III. category (Table II.), but this warning in no way impairs the general usefulness of the method of relating the chemical composition to the micro-structure of a complex bronze, as outlined above.

Crystalline Structure in Relation to Failure of Metals

This subject was chosen by Dr. H. J. Gough in the Eighth Edgar Marburg Lecture, delivered before the American Society for Testing Materials, at Chicago, on June 27, in which he outlined some of the important work he has done and discussed the conclusions formed. The lecture is briefly summarised in this article.

THE investigation of the mechanical properties of metals in relation to their crystalline structure is proving to be of great scientific and industrial importance. A knowledge of the true nature of metals, established on a sure foundation, should result, for example, in useful new alloys for the service of man, and an appreciation of the most appropriate methods of their production and treatment. Much fundamental research is required before the physical properties of metals can be expressed by simple laws, but a useful start in this direction has been made. The basic problem is the dependence of the strength and other related properties of metals on the ultimate cohesive forces of which so little is known at present. The plastic deformation that normally precedes rupture is most important.

There are difficulties in deriving knowledge of the nature of the ultimate cohesive forces, analytically, from the results of tests on materials—an alternative method is the one by which the behaviour of actual materials is reproduced in theoretical models based on assumed laws of force. Illustrations of the latter method were given in the lecture, and the importance of the Cauchy relations was emphasized. A very brief review of more recent work on the ultimate nature of cohesion in relation to the wave mechanic's view of matter was also attempted.

All atoms, even of the most complex kinds, have a tendency to group into regular assemblages; the theoretical basis for this grouping, and the simplification that it permits was indicated. Practical crystals fail to achieve this perfect regularity of structure, and the modification of behaviour which may thereby result was discussed, together with some theoretical explanations of the asymmetry which have been advanced. Some remarks on the "amorphous" state are also offered.

The mechanical properties of single crystals were discussed in detail.

Elastic constants are very important in the fundamental theory. The mechanism of distortion, by slip and twinning, of single crystals of metals and simple alloys under simple stressing systems was summarised briefly, and attention directed to the important associated phenomena, such as hardening, and to essential differences which distinguish metals. Mention was made of the observed effect of boundaries upon specimens consisting of several large crystals. The degree by which the structure of polycrystalline materials deformed by cold processes, such as rolling, drawing, extrusion, etc., can be correlated to the mechanism of distortion of single crystals, was summarised. Various theories advanced for the stress conditions governing the plastic limit and plastic flow in polycrystalline metals were reviewed, and reference made to the results of recent static and fatigue experiments, and to the heat developed during plastic flow.

An account was then given of an extensive investigation into the fatigue characteristics of single crystals. Studies have been made of the deformation and fracture of metals conforming to three representative space lattices and to one more complex lattice. It was shown that the mechanism of deformation under fatigue stresses is essentially similar to that governing the distortion of single crystals under static forces; considerable information was also acquired regarding twinning characteristics. Experiments made on two crystals tested under combined stresses showed that the process of deformation was determined entirely by the range of shear stress; the propagation of fatigue cracks was affected by normal stresses. Tests made on three specimens each consisting of two large crystals were the basis of a discussion of the nature of their failure and the effect of the crystal boundaries. Experiments on the behaviour of single crystals under "corrosion fatigue" were described.

Failure of metals, whether by static, impulsive, or fatigue stressing, and by "corrosion-fatigue" action may be closely associated with initial deviations from the primary lattice structure, and with the phenomena, such as crystal break-up and lattice distortion, which are associated with strain-hardening. X-ray evidence on the nature of hardening was discussed. All failures of crystalline materials are intimately associated, and must eventually be correlated, with the cohesive forces. A most promising field of future research lies in this direction.

Rolling Mill Furnace Fired by Town's Gas

The establishment of gas as a scientific fuel in industry is open to immense possibilities, and in this article one of many developments in its application, referred to by Mr. Joseph E. White at the recent annual meeting of the Institution of Gas Engineers, is discussed. Some factors that have influenced development are mentioned.

THERE has never been a period in industrial history when more thought has been given to the perfection of details and in securing complete scientific control. This control is the motive behind progressive management, and is the key to true appreciation of values. Thus it is found that fuels are compared less and less on the basis of the number of heat units that can be bought for the monetary unit, and more and more on the final cost basis. It is for this reason that town's gas is making progress in its application to the needs of industry, and the Newcastle and Gateshead Gas Co., under the direction of Mr. Joseph E. White, is one of the companies taking effective measures to promote its wider use.

The true development of industrial gas in the area covered by this company may be said to date from the introduction of the two-part tariff system of charges in December, 1929, since when considerable progress has been made. In this area it was appreciated that anything likely to improve efficiency and reduce costs is more eagerly sought after, and wherever possible is given a fair trial. Believing that there is a great future for town's gas in the iron and steel industry, efforts are being made to interest local steelworks' owners, with the result that sanction was given for the application of town's gas to a rolling mill furnace engaged on the reheating of slabs for sheet and plate rolling.

TABLE I.

DETAILED ACCOUNT OF A TYPICAL RUN STARTING FROM A COLD FURNACE TO THE END OF THE ROLLING PROGRAMME.
(Furnace Lighted at 6-0 a.m. Rolling at 2-0 p.m. Meter Reading, 4,046,800.)

Day.	Shift.	Meter Reading Start of Shift.	Meter Reading at End of Shift.	Average Gas Consumed per Hour.	Gas Used per Shift.	Throughput per Shift.	Consumption per Ton, Including Gas Used in Heating up Furnace.	Consumption per Ton per Shift.
1	2	3	4	5	6	7	8	9
						T. C. Q.		
Tuesday	2 p.m. to 10 p.m.	4,106,700	4,165,000	7,288	58,300	15 18 0	7,437	3,666
,,	10 p.m. to 6 a.m.	4,165,000	4,221,200	7,025	56,200	18 5 0	5,110	3,077
Wednesday	6 a.m. to 2 p.m.	4,221,200	4,273,600	6,550	52,400	15 18 0	4,536	3,296
,,	2 p.m. to 10 p.m.	4,273,600	4,329,300	6,962	55,700	13 15 1	4,427	4,051
,,	10 p.m. to 6 a.m.	4,329,300	4,386,000	7,087	56,700	17 18 1	4,151	3,169
Thursday	6 a.m. to 2 p.m.	4,386,000	4,441,200	6,900	55,200	17 14 0	3,959	3,118
,,	2 p.m. to 10 p.m.	4,441,200	4,501,400	7,525	60,200	16 1 3	3,936	3,739
,,	10 p.m. to 6 a.m.	4,501,400	4,547,700	5,800	46,300	16 3 2	3,803	2,856
Friday	6 a.m. to 2 p.m.	4,547,700	4,601,200	6,687	53,500	16 19 2	3,731	3,165
,,	2 p.m. to 10 p.m.	4,601,200	4,655,400	6,775	54 200	15 17 0	3,700	3,430
,,	10 p.m. to 6 a.m.	4,655,400	4,708,800	6,675	53,400	17 19 1	3,629	3,983
Saturday	6 a.m. to noon	4,708,800	4,753,200	7,400	44,400	15 14 0	3,564	2,828
Monday	6 a.m. to 2 p.m.	4,798,400	4,854,100	6,962	55,700	17 3 2	3,748	3,238
,,	2 p.m. to 10 p.m.	4,854,100	4,911,100	7,125	57,000	19 1 2	3,687	2,984
,,	10 p.m. to 6 a.m.	4,911,100	4,964,000	6,612	52,900	17 7 0	3,639	3,057
Tuesday	6 a.m. to 2 p.m.	4,964,000	5,017,100	6,637	53,100	17 6 2	3,606	3,069
,,	2 p.m. to 10 p.m.	5,017,100	5,072,000	6,802	54,900	18 14 1	3,562	2,935
,,	10 p.m. to 6 a.m.	5,072,000	5,123,300	6,412	51,300	18 6 1	3,517	2,803
Wednesday	6 a.m. to 2 p.m.	5,123,300	5,174,600	6,412	51,300	15 14 1	3,506	3,267
,,	2 p.m. to 10 p.m.	5,174,600	5,229,000	6,800	54,400	17 14 0	3,534	3,073
,,	10 p.m. to 6 a.m.	5,229,000	5,282,300	6,662	53,300	16 12 0	3,524	3,211
Thursday	6 a.m. to 2 p.m.	5,282,300	5,336,800	6,812	54,500	17 17 3	3,470	3,045
,,	2 p.m. to 10 p.m.	5,336,800	5,387,400	6,325	50,600	16 14 0	3,473	3,030
,,	10 p.m. to 6 a.m.	5,387,400	5,441,000	6,700	53,600	19 1 1	3,402	2,806
Friday	6 a.m. to 2 p.m.	5,441,000	5,498,800	7,225	57,800	20 7 3	3,377	2,833

SUMMARY OF RESULTS.

Total throughput ..... 430T. 3C. 2Q.
Total gas used (including that used in heating up furnace on Tuesday and Sunday) ..... 1,452,000 cub. ft.
Gas consumed per ton $\frac{1,452,000}{430\text{T. } 3\text{C. } 2\text{Q.}}$ ..... 3,377 cub. ft.
Cost at 2·475d. per therm (1s. 0¾d. per 1,000 cub. ft. of 500 B.th.u. gas) ..... 3s. 5¾d. per ton of rolled weight
Gas used in heating up furnace (Tuesday, 6 a.m. to 2 p.m.) ..... 59,900 cub. ft.
Gas used in heating up furnace (Sunday midnight to 6 a.m.) ..... 45,200 cub. ft.
Total gas used in heating up furnace ..... 105,100 cub. ft.
Gas consumed per ton (not including that used in heating up furnace) ..... 3,130 cub. ft.

TYPICAL SHEETS AND PLATES.

Steel Sheets 20G	8 ft. × 2 ft.	Steel Plates	8 ft. × 2 ft. × 1 in. thick
,, 10G	22 ft. × 2 ft.	,,	26 ft. × 2 ft. × $\frac{3}{16}$ in. ,,
,, 10G	15 ft. × 5 ft.	,,	28 ft. × 3 ft. × $\frac{3}{16}$ in. ,,

Producer gas, when generated from coal costing 14s. per ton delivered, is an extremely formidable opponent, especially when the plant has been operated under the supervision of an efficient management which has taken steps to see that the producer plant is properly handled. However, after much careful consideration as to the possibility of success, the conversion was put in hand in the manner indicated in Fig. 1. Alterations to the original

arrangement of the furnace were made in one respect only—that of cutting off the producer gas ways and substituting a multiple town's gas port below the air-ways from the regenerators. No alteration was made in either the regenerator capacity or the combustion space. A certain amount of experimental work was involved, however, in getting sufficient "travel" upon the flame to ensure a good heat right up to the furnace doors.

The final results were, to say the least, surprising to all concerned. To illustrate the high efficiency possible with town's gas on such furnaces and the nature of the results obtained, there is given in Table I. the latest detailed account of a typical run, starting from a cold furnace to the end of the rolling programme.

To arrive at true producer gas costs is not an easy matter; so many factors enter into these costs that unless a most exacting record is kept there is a decided tendency to regard producer gas as having a cost per therm very much lower than is actually the case. Fortunately, the mill owners in question were able to give a detailed account of every penny which had been spent on the furnace and producers during the six months prior to the coal-gas experiments. Six months' service with gas firing have now been completed under the same conditions. The results, which are tabulated below, may be regarded, therefore,

COMPARATIVE RESULTS OF PRODUCER GAS AND TOWN'S GAS IN STEELWORKS REHEATING PRACTICE.

Cost of Total Sheared Weight, Rolled, and Annealed.

Producer Gas.

January 1 to August, 1932.
Make, 2,187 tons.

	£	s.	d.
Gas producers' wages	97	8	2
Repairs to furnaces and gas producers	185	6	3
Removing ashes, etc.	99	0	0
Coal, 605T. 6C.	415	9	10
	£797	4	3

Town's Gas.

September, 1932, to February 28, 1933.
Make, 1635T. 12C. 1Q.

	£	s.	d.
Coal, 192T. 2C.	142	16	7
Gas, 8,072,300 cub. ft.	416	4	4
Repairs to furnace	12	16	6
	£571	17	5

as an indication of true producer gas costs and of the general suitability of town's gas in steelworks reheating practice.

Comparison of the above figures shows a direct saving by gas of 5%. There are, however, additional advantages such as decreased consumption of electrical energy on the rolls brought about by more thorough heating of the slabs, reduction in loss of weight by scale, and the saving effected in repairs caused by the closing down of the producer steam plant; the total saving may therefore be said to be between 8% and 10%.

It will be noticed that 192 tons of coal appear in the gas costs. This is explained by the fact that all the above costs are for rolling and annealing, the annealing furnace being at present coal-fired. The nature of the work passed through the gas furnace is more varied, the output being from pieces weighing about 56 lb. up to slabs weighing 1,000 lb. Control over the furnace atmosphere has been of the greatest value in reducing scale on the thinner sheets; in fact, the better soaking heat obtained together with the reducing atmosphere has resulted in a generally improved produce throughout the firm's range of limit sizes, which are from 8 ft. × 2 ft. × 1 in. thick to 18 ft. × 2 ft. × 18 in. Plates 26 ft. long by 3 ft. wide are rolled with ease.

The personal feelings of Mr. White towards the future of gas as an industrial fuel are very optimistic, and they are not without justification, because even in the Newcastle area, where the present degree of industrial depression is without precedent, it is his experience that manufacturers are becoming gas-minded by the hard school of experience and economics. The installation previously referred to is only one of the many that have been established during difficult and exacting times, and it is suggested that there is no better time to arrive at the true value of an industrial

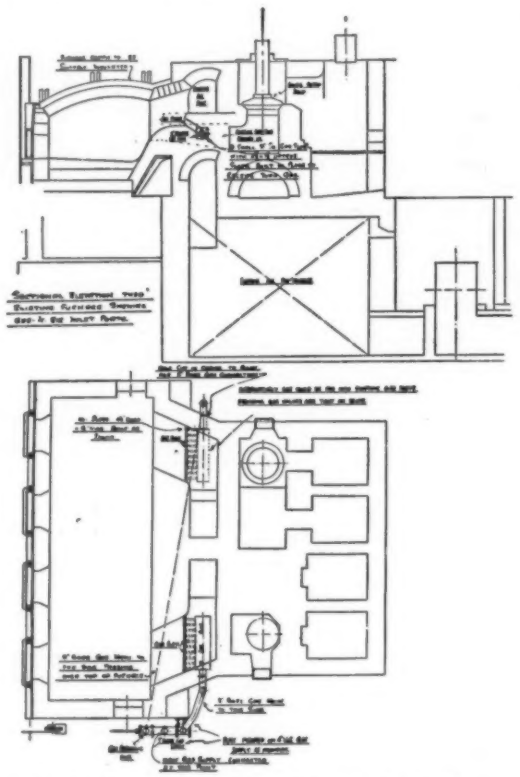


Fig. 1.—Showing conversion of furnace for town's gas.

fuel. If gas can progress in these times, there is no doubt as to the position it will occupy when the nation enters upon a period of prosperity which, sooner or later, must come.

The success achieved in this area is undoubtedly due to two main factors: adequate organisation and knowledge of the application of gas to industries, and gas charges. As a rule, consumers prefer experimental work to be done under their own direction and in circumstances as nearly approaching normal working conditions as is possible, and the organisation in the area in question is apparently efficient and able to deal with such experimental work in a very helpful manner. Much of the progress, however, is undoubtedly due to more equitable charges. Under the flat-rate system all expenses incurred are calculated and charged at so much per therm, with the result that the consumer who uses little or at times no gas is contributing little or nothing towards costs which are incurred for each consumer, and which, therefore, fall unduly on the consumers who use larger quantities of gas. The adoption of the two-rate system in this area enabled manufacturers to appreciate that a rate of charges had been drawn up primarily for industrial consumption, and they viewed it as a settlement of an outstanding grievance which industrial consumers had long felt—that it is unfair to be charged on the flat-rate system.

The third of a series of publications on the attributes of nickel alloy steels has just been issued by the Bureau of Information on Nickel, the Mond Nickel Co., Ltd., Millbank, London, S.W. 1; it is entitled "Quality with Economy in Case-hardening," and is both interesting and informative.

Corrosion and Cracking in Boiler Plates

By J. W. Donaldson, D.Sc.

Developments in steam-engine practice have introduced new problems in engineering and metallurgy and have raised serious questions as to the designs and materials required to meet them. In this article the author discusses one of the problems—that arising from failures in boiler plates while in service.

THE last ten years have seen many striking developments in engineering, and notable among these is the rapid development of steam-engine practice, which has resulted in a very great increase in working pressures and temperatures. These advances, like all other similar advances, have introduced new problems in engineering and metallurgy, and have raised serious questions as to the designs and the materials required to meet them. Failures in boilers working under ordinary conditions of temperature and pressure are not unknown, but they are extremely rare. In high-pressure boilers, however, a fair number of failures have occurred during recent years in boiler plates while in service. These failures are usually found running between rivet holes, and are sometimes accompanied by the breaking off of rivet heads. The nature of these cracks, the conditions under which they occur, and the methods which have been adopted for their prevention, have given rise to a considerable number of investigations on boiler failures and boiler materials, and have led to interesting theories and conclusions. These investigations have been carried out principally in the United States and in Germany, where most of the failures have been experienced, and also to a lesser extent in this country.

There is a remarkable similarity in the general features of all the failures. They usually occur as fine cracks in the joints extending from rivet hole to rivet hole, and microexamination of these cracks has shown that they are intercrystalline, occurring along the grain boundaries. In this respect they differ very much from cracks which usually occur in steel. When steel is fractured by tension, by bending, by impact, or when it fails, due to fatigue stresses, the cracks that develop run across the crystal grains, and not round the grain boundaries. In other words, normal cracks are transcrystalline and not intercrystalline. Intercrystalline cracking is the type of cracking which is found in brass and other alloys under certain circumstances, and which is known as "season cracking." It takes place in those alloys when they are in a state of internal strain, and when they are exposed in that condition to certain corroding media, although it has been shown in the case of certain aluminium alloys that season cracking occurs under conditions where there are no corrosive influences. It has been suggested, however, that this condition only occurs in alloys with low melting points, and that in general season crackings are the result of strain and corrosion. Whether season cracking can take place in steel under certain conditions is a subject which has given rise to a considerable amount of discussion. Nevertheless, the fact remains that there is a marked similarity between the cracks occurring in fractured boiler material and the season cracks of non-ferrous materials.

Caustic Embrittlement.

Investigations have been carried out in the United States and Germany on mild steel, to determine the conditions under which cracking, similar to that found in fractured boiler plates, is likely to occur. In 1924 a paper was published by Williams and Homerberg,[1] in which a type of fracture in mild steel, characterised by intercrystalline cracking and produced by the action of caustic-soda solution, was discussed. Test-pieces, both stressed and unstressed, were exposed to the action of sodium hydroxide solution, and such cracks developed in the pieces under stress. It was suggested by the authors that these resulted from cathodic hydrogen diffusing into fine capillaries between the grain boundaries, which were widened under stress, and that such hydrogen reduced the non-metallic segregates in the grain boundaries, forming water, which by its volume tended to fracture the steel.

Later in 1926, Parr and Straub[2] published the results of a series of investigations, and from their conclusions described the type of failure occurring in boiler plates as being due to "caustic embrittlement." In dealing with the general conditions under which cracking occurred, and the nature of the cracks, they stated that failure occurred in plates of good quality as regards composition and strength as well as in inferior plates. The nature of the cracks, without exception, followed the grain boundaries in contrast to fatigue and corrosion cracks, which developed across the grains. Sodium carbonate was the one substance invariably present in the water of boilers which had failed, sulphates being either absent or present only in small proportions.

These investigators also carried out a series of experiments, in which test-pieces of mild steels were subjected to tensile stresses while immersed in caustic-soda solutions at high temperatures under steam pressures. The results obtained from these experiments indicated that two conditions must be present simultaneously to produce cracking; first, the stressing of the material above its yield-point; and, second, the concentration of sodium hydroxide to a point which is in excess of 350 grammes per litre. Tests carried out omitting sodium hydroxide showed no effect. Variations in pressure to the extent of 200 lb. per sq. in. had no marked effect on the rate of cracking. A microscopic examination of the strained parts of the test-pieces showed the presence of a large number of intercrystalline cracks.

The high concentration of caustic soda necessary to bring about embrittlement does not usually exist in boiler water, where the concentration seldom exceeds 1,000 grains per gallon of sodium hydroxide, but it was suggested that such dilute solutions find their way into the seams between metal surfaces, and by evaporation are concentrated until their concentration attains the 20,000 grains per gallon necessary to produce embrittlement. As regards the attainment of stresses above the yield-point of the material, the authors suggest that in practically all boiler plates stresses at the edges of rivet holes probably exceed the yield-point, and that these stresses result from excessive riveting pressures.

In a second paper published in 1927, Parr and Straub[3] gave the results of further experiments on this subject. These show that embrittlement by means of caustic solutions will not proceed in the absence of a stress above the yield-point, but that such a stress has no relation to the actual yield-point of the material, but is a high stress which can be compared with the usual yield-point of boiler-plate steel. Heat-treatment of boiler plate whereby the yield-point is raised does not prevent cracking at a particular stress. It was also shown that increase in temperature caused cracking to proceed much faster in more dilute solutions

1 R. S. Williams and V. O. Homerberg, Trans. Amer. Soc. for Steel Treating, 1924 Vol. 5, p. 399.

2 S. W. Parr and F. G. Straub, Amer. Soc. for Testing Materials, June, 1926.
3 S. W. Farr and F. G. Straub, Amer. Soc. for Testing Materials, June, 1927.

of caustic soda. Various steels were also tested to determine if any particular steel was more resistant to this type of attack than another, but no steel was found to be more resistant to any marked extent. The special German steel containing 0·29% silicon, 2·13% manganese, which is claimed to be free from cracking, cracked at an appreciably faster rate than normal boiler-plate steel.

In 1930 a third paper was published by Straub[4] which contained the complete results of five years' investigations of boiler-plate embrittlement. More recent instances of embrittlement in steam boilers are dealt with, and consideration is made of the solubility of embrittlement-inhibiting agents in boiler water and the concentration of solutions in capillary spaces. Experimental work, as well as the examination of fractured boiler drums, shows that the cracking of boiler plates is brought about by the combined action of stress and chemical attack. The stresses are inherent in the construction and operation of the boiler, while the chemical attack is caused by the presence of sodium hydroxide in the water. Certain methods of water treatment were found to convert some safe waters into the characteristic type which produced embrittlement. The research also indicated that no simple material suitable for boiler plates has been found, which is resistant to the embrittling action of caustic soda. The uses and methods of introducing inhibiting agents were also dealt with, and these will be considered later.

The chemical embrittlement of boiler plates is also dealt with by Schuster[5] in a recent investigation on the mechanical breakdown of prime movers and boiler plant, and several cases are given as being due to this type of failure. All these cases show intercrystalline cracking, and it is stated by the author that it has never been possible to reproduce such cracks near the affected parts of boiler plates that have failed by embrittlement in service, when the attempt has been made independently of chemical agency. Tests made by alternate bending or by fatigue in a Wöhler testing machine were all transcrystalline. Only when test-pieces were immersed in caustic soda and subjected to stress did intercrystalline cracking occur.

The conclusions reached by Parr and Straub, as a result of their experiments, have led to a considerable amount of discussion. It has been pointed out that the name "caustic embrittlement" applied to intercrystalline cracking in riveted areas, is bad, and that although stressing of the material is necessary and the presence of caustic soda in high concentration is essential, the development of such cracks does not involve any true embrittlement of the steel. Tensile and even impact tests made in pieces taken from the vicinity of such cracks have given quite normal results, and the fractures which result from such tests have shown no tendency for the cracks to be intercrystalline, except in the case of Izod impact tests, where one of the original cracks have been included in the test-piece and have acted as an additional notch. The term "caustic embrittlement" does not indicate, therefore, that the steel is brittle, and it has been suggested that the term "caustic cracking" might be more suitably applied to this type of failure.

The concentration of caustic soda necessary to produce cracking, and the influence which caustic soda has in producing cracking, have also been critically discussed. As already indicated, the normal concentration of sodium hydroxide in a boiler is low, and if a concentration of 20,000 grains per gallon is necessary to produce cracking, this is produced by penetration of the dilute solution into seams and into crevices around the rivets, where it becomes concentrated by evaporation. It has been suggested that any rivet, whether it is driven hot or cold, is only tight to a degree, and that rivet shanks are covered with oxide to a greater or lesser depth, and that this narrow oxide-filled space or crevice between the shank and the sides of the hole acts as a capillary tube and allows the dilute caustic solution to penetrate to parts where it becomes concentrated. Whether such a small volume of the solution as would remain after a high degree of concentration has taken place would be sufficient to produce cracking is very doubtful, as is also the question of the renewal of the strength of the solution by continual seepage and concentration of the dilute solution.

The stressing of material above its yield-point is a necessary condition in the conclusions arrived at by Parr and Straub. The working stresses of a boiler due to steam pressures are far below the yield-point of boiler-plate steel. Certain stresses are set up both in plates and rivets, due to the pressure of riveting, but whether those additional stresses are sufficiently high to bring the material within the dangerous range, it is difficult to estimate. To these, however, must be added in many cases severe local stresses resulting from the various methods of riveting and caulking which take place in boiler construction, so that it appears possible for the stress condition necessary for caustic attack to be attained. It has been pointed out recently that all cases of cracking are not due to caustic attack, and that intercrystalline cracking has developed in boiler drums and tubes where the material was only subjected to stress. Such results, however, are not supported by Rosenhain and Hanson's[6] investigations, where a very low carbon steel was subjected to prolonged tests at 300° C. for a period of five years, and where no cracking resulted.

While many engineers, chemists, and metallurgists agree that concentrated solutions of sodium hydroxide do produce cracking, they do not agree that such solutions are necessary, and suggest that there are other factors operating as well as the stressing of material and caustic attack. It has been stated that gaseous hydrogen may be produced inside a boiler even in the absence of sodium hydroxide, and that this gas penetrates the steel, rendering it brittle. It is also well known that dissolved atmospheric oxygen in boiler-feed water is a cause of corrosion, it was stated recently that the amount of corrosion is directly proportional to the amount of dissolved oxygen. Evans[7] has shown that corrosion by water containing oxygen is due to differential aeration of the oxygen, and that corrosion will be concentrated in parts relatively inaccessible to oxygen. He has also pointed out that if incipient cracks radiate from rivet holes, and if there are spaces between the rivets and the plate, or if the material of rivets shows porosity, corrosion will penetrate to these parts, due to differential aeration, and enlarge and extend the cracks. Acid waters containing magnesium chloride will also attack steel, even in the absence of oxygen, with the liberation of free hydrogen gas, which acts upon and corrodes the material.

To investigate still further the influence of chemical embrittlement on boiler material, researches are at present being carried out at the National Physical Laboratory with a view to obtaining definite data on this much-discussed subject. Tests are being made on boiler-plate material stressed under pressure at high temperatures in various corroding media. Further prolonged loading tests of five years' duration are also being carried out on boiler-plate steel at 300° C.

To be continued:

4 F. G. Straub, Illinois Univ., Eng.Exp.Station, 1930, Bulletin No. 216.
5 L. W. Schuster, Inst.Mech.Engs., Apl., 1933.

6 W. Rosenhain and D. Hanson, *Journ. Iron and Steel Inst.*, 1927, Vol. 116, p. 117.
7 U. R. Evans, "Corrosion of Materials," p. 72.

Errata (June issue).

On page 37, caption to Fig. 1, delete "Lightly etched in 10 % HCl, etc.," and delete "Etched in HCl, etc." from Fig. 4, page 38.

On page 44, the title of the article following the correspondence should read "The Estimation of Small Proportions of Bismuth in Copper (up to 0.02 %.)" A similar alteration should be made on the Contents page and on the Index Card.

On page 49, caption to Fig. 3, delete "rapideep" and insert the words "alkaline earth bath." The footnote on this page should read: A British patent has been taken out covering the manufacture and use of such baths.

Non-Metallic Inclusions in Steel

Steel Specifications are becoming more exacting, not only in regard to physical properties and chemical analysis, but also in regard to cleanliness. The rejection of steel for the lack of cleanliness is increasing, but cleanliness is one of the most difficult requirements for the manufacturer to fill. In this article an electrolytic method for the determination of inclusions in plain carbon steels is discussed.

CLEANLINESS in steel refers particularly to the absence of oxide and sulphide inclusions. Other foreign particles, such as furnace or ladle slag, ladle and runner brick, etc., must also be absent. At present the determination of cleanliness is usually made by microscopic inspection or macroetching. Through lack of it, the rejection of steel is increasing, yet it is one of the most difficult requirements for the manufacturer to fulfil. This is due to the fact that there are many different conceptions of what constitutes a clean steel; a material that may be considered entirely satisfactory by one consumer is rejected by another. The cause of this confusion and disagreement concerning the definition of a clean or a dirty steel is simply that as yet no standardised procedure for the determination of impurities has been proposed and generally accepted, since many variables are encountered which interfere with the development of a satisfactory method.

The inclusion materials which usually exist in steel may be classified into two general types—namely, oxides and sulphides. Many combinations of oxides, such as the silicates, have been recognised in steel, as well as combinations of such sulphides as FeS and MnS. Up to the present the only method which has been proposed for the determination of FeS and MnS in plain-carbon steels is the electrolytic procedure.[1] All of the other methods have been concerned with the determination of oxides and their combinations. In most cases the originators recommended their method for the determination of all types of oxide inclusions (including FeO) from all types of steel. Also, in most of these cases the results obtained have been questionable, even for some of the simple types of steels. In general, some of the oxides, particularly MnO and the sulphides, are attacked and dissolved, thus giving low results, and at the same time other factors tend to contaminate the inclusion residue and to give high results. The balance between these two conditions constitutes the reported analysis.

It is improbable that a procedure which will determine all types of inclusions from all types of steels will ever be established. In order to obtain the oxide and sulphide contents of all types of steels many and distinctly different methods will probably be needed.

The principal methods which are used to-day include :—

1. The vacuum fusion for the determination of total oxygen. (Its accuracy is still unknown.[2])
2. The modified Ledebur method for the determination of FeO. (Absolute accuracy still undetermined.)
3. The modified Kichline. (Accurate for Al_2O_3 in aluminium-killed steels.)
4. The electrolytic. (Accurate for MnO, MnS, FeS, SiO_2, and Al_2O_3 in plain and low carbon steels only.)

The development of the fourth method is described at considerable length by Messrs. G. R. Fitterer, B. E. Sockman, E. A. Knockenberger, R. B. Meneilly, E. W. Marshall, jun., and J. F. Eckel, in the U.S. Bureau of Mines Report of Investigations, 3205. According to this paper, the first experimental work on electrolytic extraction was done by Eckel[3] in 1927, who attempted to dissolve electrolytically the steel anode in a moving electrolytic containing $FeSO_4$, $FeCl_2$, and $(NH_4)_2SO_4$. An alumina dialysing cup was used to separate the anode from the cathode. Difficulty was encountered, due to the formation of certain basic iron salts. An attempt to overcome this was made by covering the electrolyte with oil to prevent oxidation, and increasing the acidity, but other conditions were encountered which were rather discouraging. It seemed necessary at that time to maintain reducing conditions so as to prevent oxidation of the iron salts. Hence Marshall[4] attempted electrolysis in ferrous sulphate electrolytes under several atmospheres pressure of hydrogen. In this case considerable hydroxide precipitation was encountered, although the basic salts did not form. Several other types of cells were devised by this investigator, but with similar results. Hence it became apparent that a study of the hydrogen-ion concentration was essential for successful electrolysis and inclusion determination. In this connection Marshall studied the effect of certain buffer solutions on a 30% ferrous sulphate electrolyte. He found that the H-iron concentration could be maintained at $10^{-6.73}$ by means of tartrate solutions, but simultaneously a basic iron tartrate precipitation contaminated the inclusion residue. A similar condition was encountered in connection with the citrate solution, but in this case the H-iron concentration was not easily controlled. Meneilly[5] was the next to work on this problem. Three main improvements resulted from his work, from which was evolved the method now being used.[1] These changes were :—

1. The concentration of $FeSO_4$ was decreased to approximately 3% to decrease hydrolysis.
2. NaCl was added to increase conductivity of a solution of such low H-iron concentration.
3. A collodion bag (dialyzer) was used to separate the anode from the cathode portions of the cell, and to trap the falling inclusion residue.

Krockenberger[6] next studied the change of H-ion concentration of the electrolyte in the anode compartment both with and without electrolysis.

The data obtained from these experiments and work done by the other authors of this paper were all correlated in such a manner that the method recommended by Fitterer[1] was finally selected. The data on which this development was based are described in this paper.

The electrolytic procedure has been previously described in detail by Fitterer[1] in such a way that any steel plant chemist should be able to follow the directions and obtain fair accuracy after some experience. Some precautions are necessary which were listed in the previous publication. The method will be briefly described for the purpose of clarity.

The steel specimen, weighing at least 50 grms., is soldered to a platinum wire and suspended from a copper bus-bar. A kink is made in the platinum wire above which is suspended a rubber block, which serves as a support for the collodion (or cellophane) bag, which surrounds the sample. This dialyzing bag is first partially filled with electrolyte and then brought up and around the sample, after which the open end is tied above the rubber block.

The collodion bags containing the samples and some electrolyte are immersed in the tank solution. The walls of this tank are made of copper sheet, and serve as cathodes during electrolysis. The bus-bar upon which the samples and the bags are suspended is attached to the positive terminal and is insulated from the main part of the tank or cathode. About 10 liters of electrolyte, containing 3% $FeSO_4$, $7H_2O$ and 1% NaCl in water, is used in each tank.

After approximately six samples have been placed in the tank, the current is turned on so that there are approximately 6 to 7 amperes per tank or 1 ampere per sample. The potential across the electrodes is approximately 3 to 4 volts. The source of power can be either a large battery

charger or any d.c. current regulated by means of a lamp-bank series of resistances.

Theory of Electrolysis.

The theory of the electrolytic procedure may be briefly described in the following manner. As soon as the power is turned on, the iron anode receives a positive charge. In doing this the iron becomes ionised with two positive charges, through the loss of two electrons, and passes into the solution at the rate of approximately 1 grm. per hour for each sample. These iron ions then pass from the electrolyte inside the collodion bag through the walls of this membrane, and finally into the external electrolyte. From this point they pass directly to the nearest wall of the tank, where they are deposited as metallic iron. Hence the iron anode gradually decreases in weight and after 24 hours approximately 24 grms. of steel will be electrolytically dissolved. During this process most of the non-metallic inclusions fall from the iron anode to the bottom of the collodion bag, where they are retained. It is believed that the pores of the collodion bag are small enough to retain these oxide particles and yet are sufficiently large for the passage of the iron ions.

After the 24-hour period, the inclusion residue at the bottom of the bag has become sufficiently large for an accurate analysis. The electrolysed sample and collodion bag are then removed from the cell and the exterior of the bag is washed with water. The collodion bag is then opened and the contents collected in a beaker. Any non-metallic material still adhering to the iron anode is scraped off and the sample washed free from such particles. This suspension is then filtered and washed about six times with warm water.

Analytical Procedure.

The residue on the filter paper contains $Fe(OH)_2$, $Fe(OH)_3$, FeO (not determined by this procedure), graphite, FeS, MnO, MnS, SiO_2, Al_2O_3, and their many combinations. The paper is dried, folded, and placed in a clean platinum crucible, and ignited for one hour at a low temperature (just sufficient to ignite the paper). The detailed analytical procedure is given by Fitterer.[1]

Each analyst has a preference for analytical procedures. The methods used by the authors are briefly mentioned in the following discussion :—

After fusion with sodium carbonate, the SiO_2 is determined in the usual manner with hydrofluoric acid. Al_2O_3 may be determined by sodium hydroxide, the phosphate method, or by the iron-aluminium hydroxide separation method. The procedure generally used at the Bureau of Mines is the sodium hydroxide separation. The total manganese present as MnO + MnS is determined by the usual bismuthate method, and a recommendation has been made for the separation of these two materials. It has been found, as will be shown in this paper, that MnO is entirely soluble in the sodium citrate solution, whereas manganese sulphide is entirely insoluble. This permits the separation of the two, and also provides a means for determining the quantity of FeS present by difference.

Determination of Non-Metallic Inclusions in Carbon Steels.

The conclusions arrived at as a result of investigations to determine inclusions in both carbon and alloy steels may be briefly summarised as follows :—

Determination of FeO.—Crystalline ferrous oxide is not soluble in the recommended electrolyte. Basic ferric sulphate and ferrous hydroxide precipitate during electrolysis and contaminate the residue so that no FeO determination can be made. Falling particles of metallic iron do not appreciably contaminate the electrolytic residue. FeO can be determined in more acid solutions having automatically controlled hydrogen-ion concentrations.

Determination of MnO.—Pure MnO is insoluble in the electrolyte. MnO is partially soluble when the MnO inclusion is in contact with both the anode and the electrolyte. Galvanic action seems to induce solubility, which varies from 0 to 30%. When MnO is combined with other oxide materials, such as FeO, SiO_2, Al_2O_3, etc., this induced solubility of MnO is reduced and in most cases is zero. No basic manganous sulphate, $Mn(OH)SO_4$, is formed during electrolysis in this solution. $Mn(OH)_2$ probably forms but does not exceed its solubility product, and therefore does not precipitate. The alloy manganese which goes into solution together with the metallic iron does not contaminate the residue. Either cellophane or collodion bags may be used for MnO determination.

Determination of SiO_2.—SiO_2 is entirely insoluble in the electrolyte, even when combined with other oxides, such as MnO. No contamination results in steels containing up to 0·9% Si. The residual silicon apparently goes into solution as silicic acid, but does not precipitate as the gel, due to the low H+ ion concentration of the solution. The silicic acid molecular complex is sufficiently small to migrate through the pores of either collodion or cellophane bags. Cellophane is just as satisfactory as collodion for the determination of SiO_2.

Determination of Al_2O_3.—Al_2O_3 is entirely insoluble in the electrolyte. The electrolytic method is probably much more satisfactory for the determination of Al_2O_3 in steels partially deoxidised with aluminium than is the modified Kichline method. Iron and manganese aluminates and aluminium silicates are present in steels of this type. These materials are soluble in the concentrated HCl used in the latter method, whereas they are entirely insoluble in the recommended electrolyte.

Determination of MnS.—MnS is insoluble in the electrolyte, and is recovered in the electrolytic residue. This compound may be separated from MnO by means of sodium citrate solution. MnO is soluble in this solution, whereas MnS is not.

Determination of FeS.—FeS is entirely insoluble in the electrolyte, and is recovered without loss in the electrolytic residue. The best method of determination of FeS is by difference between the value of total sulphur in the steel and the sulphur as MnS, which gives the remainder as FeS.

Determination of Oxides and Sulphides in Alloy Steels.

Too many variables are presented for the determination of alloy oxides and sulphides by means of this electrolytic method. The method is recommended only for low-carbon and plain-carbon steels.

Cr_2O_3 may be determined by dissolving the steel in a weak sulphuric acid solution and separating the carbides from the oxides in the residue by means of the selective action of chlorine upon the carbide. At 500° C. the carbide is entirely removed, whereas the oxide is not attacked.

The results of these investigations show that nickel sulphide probably exists as an inclusion in steel.

Molybdenum sulphide also is a possible inclusion.

Copper sulphide may also exist as an inclusion in steel. New methods must be devised for the determination of oxides and sulphides in each class of alloy steels. Entirely different problems are presented by each type of steel, and the solution of these problems for any one class will not necessarily apply to any other. The electrolytic method presents some very marked possibilities in certain cases, but apparently will be useless for the determination of non-metallic inclusions in some of the alloy steels.

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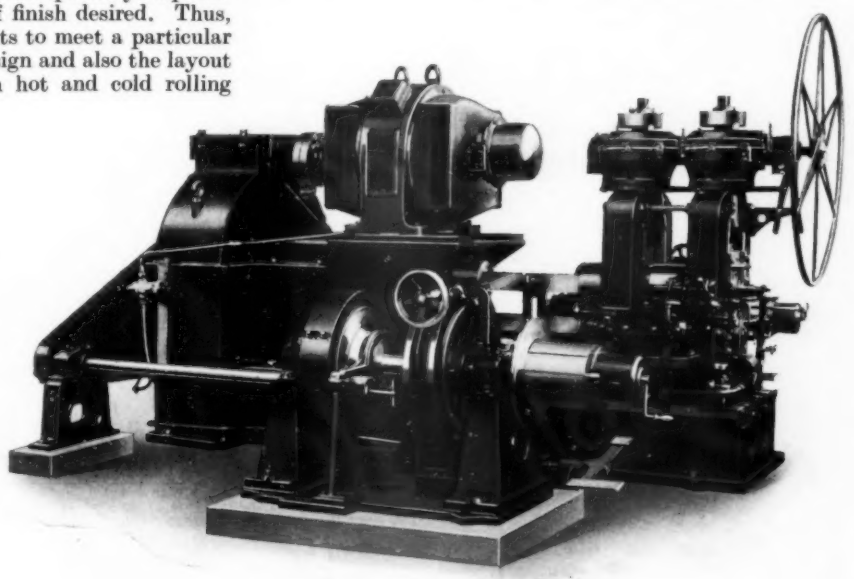
Recent Developments in Tools and Equipment

AN IMPROVED 10 in. HIGH-SPEED REVERSIBLE COLD ROLLING MILL.

For Steel and Non-Ferrous Metal Strip.

ACCURACY and high finish, as well as increased speed of production, are essential to an improved quality of product from rolling-mill plant, and in view of the wide range of metals and alloys now available, considerable developments have been made in rolling-mill design, with the object of meeting these requirements, and at the same time to ensure maximum efficiency in the operation of the mill. Many factors influence the design of a mill, the most important of which concern the type of material to be rolled, the thickness, width, and quantity required in a given time, and the quality of finish desired. Thus, to cover adequately the requirements to meet a particular material and form of rolling, the design and also the layout of the mill plant varies. In both hot and cold rolling equipment, however, considerable progress has been made during recent years, and improvements continue to be incorporated in an effort to reduce the operating costs and to maintain or improve the quality of the rolled product. A noteworthy example of developments in this direction is the latest design of cold-strip rolling mill developed by W. H. A. Robertson and Co., Ltd., of Bedford. This mill is of the high-speed reversing type, and is claimed to provide accuracy and finish of product to the most exacting requirements. Designed for the economical rolling of steel strip in hard and soft qualities, in addition to non-ferrous metals of all classes, it includes many features of outstanding interest as will be appreciated in the following brief description.



10-in. High Speed Reversible Cold Rolling Mill.

The mill, which is shown in the accompanying illustration, includes all the standard features of a high-grade strip finishing mill. For instance, it is fitted with hardened chrome steel rolls which are ground and polished and hardened to between 95 and 100 Scleroscope; "Flood" lubrication roll bearings of Robertson's latest patent design are incorporated; these are of the totally enclosed type, the bearings forming an oil chamber through which suitable filtered and cooled oil is pumped continuously under low pressure. The rolls are driven from totally enclosed double-helical driving gears, through balanced couplings, the teeth of which are lubricated by means of an oil spray and the shafts of which run in roller-bearings. The mill is arranged for direct drive from a variable speed reversing motor which is mounted above the gearbox; as will be seen in the illustration, this arrangement reduces to a minimum the floor-space required.

In addition to these standard features, a number of unique improvements are incorporated in this new design which indicate the trend of development. The variable speed drive and reversibility, for instance, is designed to give a maximum rolling speed of 300 ft. per min. A specially designed roll adjustment enables the operator to apply pressure with the strip in the rolls. Improved guides are arranged on both sides of the rolls, which are specially designed to facilitate quick adjustment and release for reversible rolling. The side guides are of the roller type and are easily and accurately adjusted. A special clamp with hard wood faces being operated with lever and cam. Two coilers are fitted, one on each side of the rolls, the drums of which are of the collapsible type, being exceptionally rigid in construction, and designed for carrying heavy coils up to a weight of 10 cwt. The release of the coils is quickly effected by means of a crank handle, which operates a screw, providing adequate collapse. These coilers are driven by an enclosed chain gear from the mill through machine-cut spur gears, while a powerful friction clutch is fitted to regulate coiling tension, and a brake to control the entry of the strip. With reversible rolling the clutch and brake are used alternatively, and both are controlled, through interlocked lever and toggle mechanism, by a foot pedal, which provides for quick starting and stopping, and instantaneous release of the brake. A micrometer screw adjustment is fitted for accurate regulation of the coiling tension.

A further interesting feature of this mill is the provision it makes for the convenient gauging of strip during rolling, and while the mill is operating at the maximum practicable rolling speed. It is noteworthy also that any speed from a "creep" up to a maximum of 300 ft. per min. is under the instantaneous control of the operator.

The roll housings consist of steel castings, and are designed to provide exceptional rigidity when the mill is in operation, and to eliminate any appreciable stretch under maximum roll loads. The top rolls are adjustable by means of a large handwheel operating large diameter high-tensile steel screws through totally enclosed machine-cut worm gearing, the ratio of which provides for the application of heavy pressure with relatively light effort on the part of the operator. Graduated index dials are fitted to the screws to show roll setting, and clutches provide for independent adjustment of each screw. Both rolls and bearings are provided with internal water circulation, while lubricating oil is pumped from a reservoir contained in the mill bed to which the oil returns. The reservoir is fitted with a copper pipe cooling coil to ensure a supply of cool

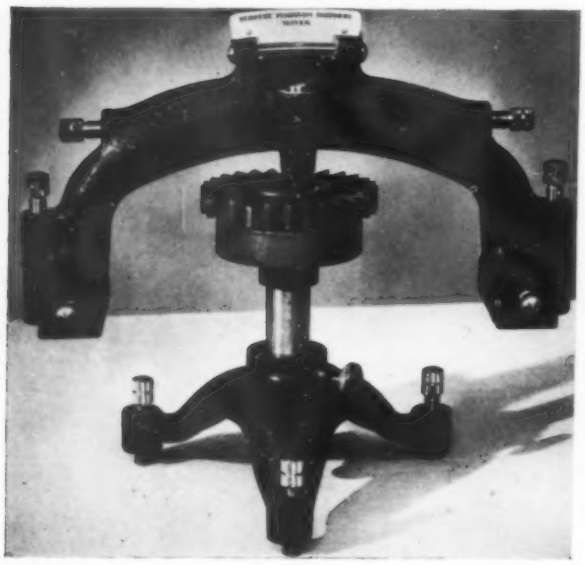
lubricant to the bearings, while an oil filter is fitted between the reservoir and bearings. The supply of oil to the bearings is regulated by suitable control valves. The bearing surfaces are lined with antifriction metal, contained in bronze bushes and fitted in steel chocks. The lower roll chocks are mounted on self-aligning pads.

The economical range of work which can be handled by mills of this new design is a strip 6 in. to 8 in. wide, reducing from about 0·08 in. thick and finishing in a series of heavy reductions to the thinnest strip required. It is claimed that the majority of requirements in cold-rolled steel strip can be obtained in three reversing passes from hot-rolled strip, without intermediate annealing, and with reductions of 33 to 40%. The minimum speed at which the mill operates on the heaviest reduction is not less than 150 ft. per min., while most finishing passes are accomplished at the full speed of 300 ft. per min.

A 120 h.p. motor is recommended for maximum production, and extensive tests have shown that the power consumption per ton of strip finished per hour is very low, while the accuracy and finish of the strip is of a very high order. Larger mills, having the same essential features, are built for wider strip in two-high and four-high types.

A Simplified Model of the Standard "Herbert" Pendulum Hardness Tester

THE number of special steels, widely different in their properties, which may be in various stages of progress in the modern engineering shop, has made the possession of a simple, accurate, and easily portable hardness tester a practical necessity. For straightforward hardness testing in the shop it is noteworthy that a cheaper, simplified model of the standard "Herbert" pendulum Hardness tester has been recently designed.



A simplified model of "Herbert" Pendulum Hardness Tester.

This is the "S.S." model, as shown in the accompanying illustration. It consists of an arched weight of 4 kilogs., resting on a steel ball of 1 mm. dia., held in a chuck, so that the constants of the instrument and the readings obtained are identical with the "Herbert" pendulum hardness tester. As with the standard model, a 1-mm. spherical diamond can be supplied as an extra with the S.S. model. Similarly, six balancing screws are provided for adjustment, and for bringing the centre of gravity of the instrument $\frac{1}{10}$ mm. below the centre of the ball. This new model is surmounted by a curved spirit-level, which has a short ivorine scale marked only for taking "time-hardness tests." A circular spirit-level is fixed for cross-levelling purposes.

The instrument is extremely simple in use; it is placed on the specimen to be tested and set swinging through a small arc. The time of swing is taken with a stop-watch, and the number of seconds occupied by ten single swings is the time-hardness number. To convert the latter—T, to Brinell, B, when the steel ball is used :—

$$B = 10\,T \text{ when } T > 28$$
$$B = 0{\cdot}36\,T^2 \text{ when } T < 28$$

It will be observed that on hard materials the conversion is ideally simple.

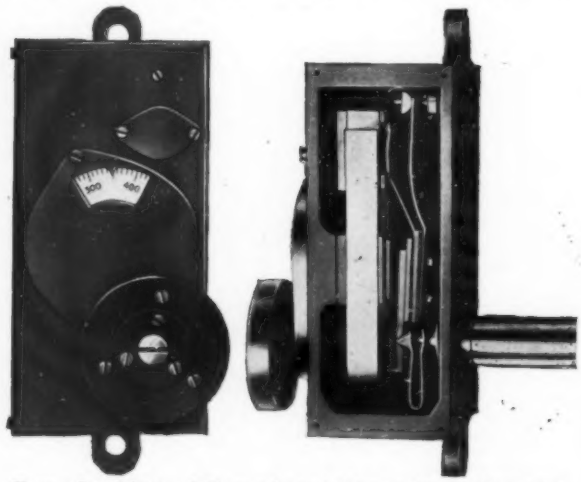
When 1-mm. diamond is used :—

$$B = 13{\cdot}5\,D \text{ when } D > 22{\cdot}5$$
$$B = 0{\cdot}54\,D^2 + 30 \text{ when } D < 22{\cdot}5$$
$$D = \text{diamond time-hardness number.}$$

The S.S. pendulum is supplied with an adjustable levelling table, having a sunken glass top which can be used for calibrating the instrument. It is assumed that a stop watch will be available in most shops, but otherwise one can be supplied with the instrument as an extra. Flat surfaces 6 in. wide, or cylinders 8 in. diameter, can be spanned by both models of the pendulum. The instrument and levelling table fit compactly into a box 14 in. × $10\frac{1}{4}$ in. × $7\frac{5}{8}$ in. deep, and the weight of the outfit is 22 lb.

A New Furnace Thermostat

THE General Electric Co., Ltd., of Magnet House, Kingsway, London, W.C. 2, have recently designed and manufactured a thermostat especially for controlling the load of ovens and furnaces for temperatures up to 600° C. The operation of the thermostat depends upon two materials expanding at different rates, and special attention has been given to their correct selection to maintain consistency in calibration and to avoid the troublesome effect of creep. These materials form an outer tube and an inner non-expanding rod which constitute the active portion of the thermostat.

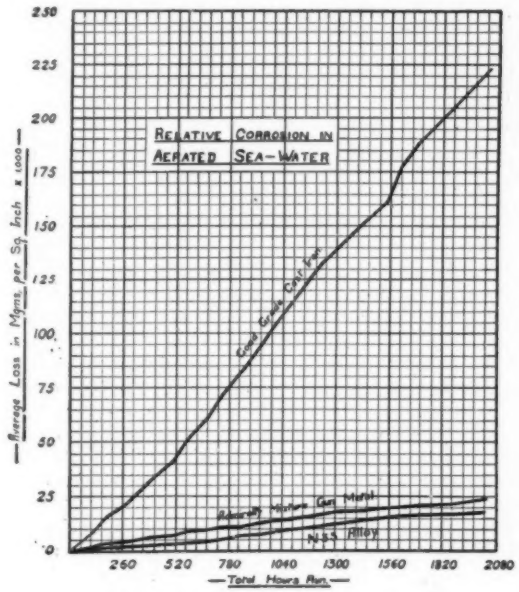


External and internal illustrations of this new furnace thermostat.

The difference of expansion of these parts actuates levers which operate the switching mechanism. The electrical part of the thermostat is arranged for dealing directly with loads of 15 amps. up to 250 volts a.c. and 10 amps. up to 250 volts d.c. For higher loadings the thermostat should be used in conjunction with contactors; on d.c. circuits a small condenser is required to be connected in parallel with the contactor operating coil. The switch mechanism is of the quick make-and-break action, and fitted with a magnetic blowout. In the standard type the length of the outer tube is 24 in., but longer tubes are available to meet requirements; with longer tubes, however, supports must be provided.

A New Pump Alloy—N 33

THE economic stress resulting from present industrial conditions has necessitated a constant search for improved methods of production. Investigations have been directed towards reducing the initial cost of the product and increasing its serviceable life, and remarkable successes have been achieved as a result. In many of these developments the metallurgist has played an important part, notably in those materials now available which have great durability against the corrosive effects of various



Relative corrosion in aerated Sea-water.

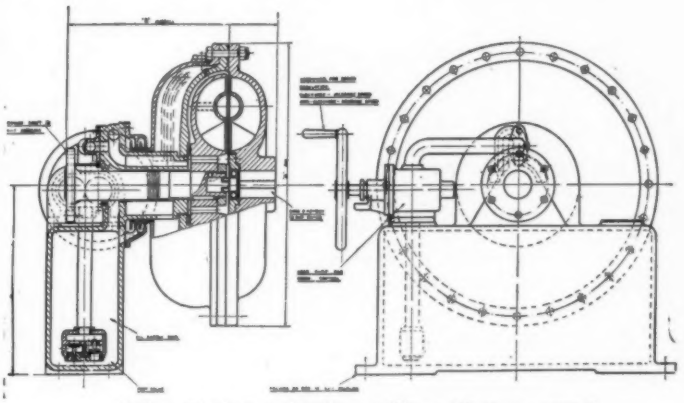
media with which they are in contact. Modern conditions demand, for instance, that pump parts must last longer and without any increase in cost. The material more generally used for this purpose is gunmetal, which is by no means immune from the various troubles to which such parts are liable. Gunmetal is relatively soft, and does not withstand erosion well, particularly that resulting from air in the suction line, which produces the effect generally known as cavitation. In this respect cast iron is superior, but it is liable to corrosion caused by the chemical attack of sea water. Where there is high pressure and whirling, an impeller may be completely worn out in a very short time. For such duties an alloy having the erosion resistance of cast iron, combined with the corrosion resistance of gunmetal, would have considerable value, and a recently developed alloy, composed largely of cast iron, but containing suitable proportions of nickel, copper, and chromium, is claimed to satisfy these requirements.

The material, which is known as N 33 Alloy, is less expensive than gunmetal, and is much harder; it thus resists more adequately the effects of erosion, while results of tests indicate that it offers greater resistance to the corrosive influences of sea-water. The accompanying graph shows the results of three typical alloys selected from a series of sixteen different alloys investigated. The methcd adopted afforded an adequate means of assessing, the relative corrodibility of different alloys from the effects of aerated sea-water.

This new alloy, which has been developed at the works of W. H. Allen, Sons and Co., Ltd., Bedford, by Mr. R. T. Rolfe, has an austenitic structure, the carbon being present largely in the form of solid solution austenite, resulting in a more homogeneous alloy than cast iron, and the electrolytic effects are considerably reduced. Recently an impeller casting in this alloy, weighing 7 cwt., was put into commission by a Water Board, and it will be interesting to see the improvement in pump performance and the extent of the reduction in maintenance costs from its use over a long period in comparison with other alloys previously used for the purpose.

Variable Speed Driving with Pump Control

OF great interest in the field of power driving is that the Hydraulic Coupling and Engineering Co., Ltd., of London (Worton Road, Isleworth), have recently placed on the market a simpler and cheaper form of their now well-known "Vulcan-Sinclair" infinitely variable hydraulic coupling. This is described as the "scoop tube coupling with pump control," particularly intended, as in the case of the scoop tube type with gravity tank and weir control, for fans, centrifugal pumps, mechanical stokers, coal and coke conveyors, and many other applications, especially when using A.C. motors.

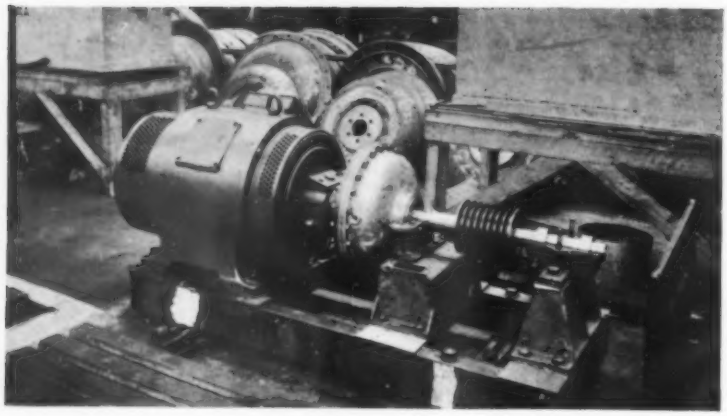


Vulcan-Sinclair hydraulic coupling with pump control.

In general principle this new design is the same as the gravity tank and weir control coupling in which connection it may be stated equipment to the extent of some 50,000 h.p. is running or being installed, especially for induced and forced draught fans.

The outstanding improvement attained by "pump control" is the elimination of the gravity tank, control weir, and interconnecting piping, giving a self-contained and very compact arrangement. Thus, the oil reservoir is now mounted on the bedplate immediately alongside the coupling, and supports the stationary housing carrying the scoop tube. A small gear pump, by means of which the oil content can be increased or decreased at will, is situated on the reservoir, and this pump can readily be arranged for hand operation, or for "distance" control with a small electric motor. Normally, upon starting there is no oil in the coupling, so that squirrel-cage motors can be used for general power driving since full speed under light load conditions is allowed without difficulty. Then, by turning the gear pump in a clockwise direction the oil is pumped into the coupling and the speed is thus raised to the desired point. Conversely, counter clockwise motion of the gear pump decreases the speed by withdrawing oil from the coupling and returning it to the reservoir, and upon shutting down the pump is rotated in the anti-clockwise direction so as to empty the coupling, thus preparing the unit for the next light load start.

Both the driving and driven elements of the "Vulcan-Sinclair" coupling are provided with radial vanes, and are separated by a gap of about $\frac{1}{8}$ in., across which the power is transmitted by the kinetic energy of the oil. That is, the impeller, acting as a centrifugal pump, discharges the oil against the vanes of the runner and drives it like a turbine, with absolutely smooth and noiseless working, the principle being the same as the "fluid flywheel" in automobile engineering.



"Vulcan-Sinclair" infinitely variable speed gear, new pump control type, representing a typical small installation driving a ventilating fan by means of an electric motor and rope pulley.

A range of smaller sizes of the new scoop tube hydraulic coupling with "pump control" is now available, and for substantially constant torque applications the hydraulic circuit formed by the impeller and runner is modified to give stable speed control under all conditions of torque and speed over a range down to about 10% of the motor speed.

Rolls for Finishing Stainless Strip

STAINLESS steel strip must compete with the finest nickel and chromium-plated work, says Edward E. Heck.* This necessitates an unusual degree of finish on the strip, and likewise on the rolls producing it. Abrasive finishing operations on super-finished rolls begin where finishing practices on ordinary cold rolls end. No universally accepted standards of surface or finish exist, thus there is disagreement as to what constitutes a perfect roll surface. Often a high lustre disguises an unsatisfactory surface which in practice soon breaks down and mars the work. On the other hand, a matt or dull finish may represent a perfect surface.

The rolls for stainless steel strip must first be ground to commercially perfect geometric accuracy, but in addition should have a so-called mirror finish. The reason for such surface perfection is obviously to avoid the reproduction of a pattern on the surface of the strip by any irregularity of the roll surface. Since the strainless strip is usually polished under flexible buffing wheels, it can easily be appreciated that any marks left by the rolls must be removed by additional buffing at extra cost.

Details of the exact abrasive process used in the rolling and grinding are constantly being varied with the idea of improving the final result. The first grinding or roughing is performed with a 150-grit, grade R, load 24, wheel supplied by the Carborundum Co. The wheel is 24 in. diameter and 3 in. wide, with an 8-in. bore. The wheel speed is held carefully to 796 r.p.m., giving a surface speed of 5,000 ft. per min., while the roll revolves at 100 r.p.m. Maximum allowable stock removal of the first grinding is 0·010 in. on the diameter. Usually three cuts are taken in the first grinding process.

A special synthetic resin bond, fine-grit wheel, also made by the Carborundum Co., and specified as K H M grade 12, bond K 12 Y, is used for the second grinding operation. Although the same size as the roughing wheel, the speed is increased to 1,034 r.p.m., giving a surface speed of 6,500 ft. per min., and maximum stock removal is 0·003 in. on the diameter. For the final process the wheel used is known as K A M, bond 910 E, and supplied by the same manufacturers. The grit is of the same order of fineness as the 600-grit powders, but is in fact finer, being graded by an elaboration of the process followed in grading abrasive powders by flotation.

Rolls, after grinding, are placed on finishing mills (last stand), where they have a life of approximately 8 hours; they are transferred to the second stand, and subsequently to the roughing stand as the surface deteriorates before regrinding.

* *Steel*, vol. 93, No. 1, page 25.

Efficient Machinery Guards

"SAFETY FIRST" is now a generally accepted maxim in reference to road traffic risks, but, nevertheless, the impulse to take an unnecessary risk seems ineradicable with most people. In effect, the principle of "safety first" is constantly affirmed, but, like many other principles designed for our benefit, fails to function or its guidance is frequently ignored precisely when it should be most implicitly obeyed—the average person is always liable to "chance it," unless restrained by something more tangible than a formula or a slogan.

This is particularly the case with machinery in factories and workshops, and unless actually prevented by the most efficient type of machinery guard, many accidents will inevitably happen. The factory owner is legally bound to make proper provision against accidents. He is also liable to heavy penalties if the safety devices applicable to the circumstance are found to be inadequate, and in addition substantial compensation has to be paid.

Apart from the legal obligation, the provision of effective machinery guards is the best method of insuring against accidents. The cost of such protection is almost negligible as compared with the liabilities arising from the lack of adequate protection. Again, the smooth running of a factory is disturbed by accidents, the moral effect of which merely from the point of view of self-interest, can and should be prevented. Furthermore, insurance companies have been known to increase their premiums in the case of factories where accidents frequently occur.

It is evident that legally, morally, and from mere self-interest, the guarding of machinery should be totally removed from any perfunctory compliance with regulations. Unguarded driving belts or pulleys are always potential sources of danger. Yet we have seen machines that otherwise were adequately protected with belt and pulley left unguarded.

Probably the most satisfactory type of guard for machinery, belts, or pulleys is strong wire mesh on stout steel rod frames. Belts and pulleys are sometimes guarded by being boarded in, but wood has the serious disadvantage of adding to the fire risk and inspection is not so easily effected as with wire mesh guards.

These guards are also equally effective when applied to actual machine operation. Whilst affording adequate protection, they do not interfere with the efficient operation of the machine and have an advantage over the solid type of guard in that they enable the operator to see the work.

In special circumstances, such as where the extreme limit of security is required, or where a smarter appearance is desired, as in certain parts of an electric power station, an excellent alternative material for guards is provided by perforated metal—steel, brass, or copper. A wide variety of patterns is available, many of which are of an extremely pleasing character.

Decoration Conferred on Sir Robt. Hadfield

H.M. the King of Italy has been pleased to honour Sir Robert A. Hadfield, Bart., F.R.S., by conferring upon him the decoration of Commendatore of the Order of the Crown of Italy, in recognition of his general scientific work. The Order was founded by Victor Emmanuel II., in 1868, to commemorate the annexation of Venetia.

Business Notes and News

Ironworks Reconstruction in Scotland

Owing to the reduced consumption of iron and the competition of pig iron from other countries, especially India, the number of furnaces in blast in Scotland has been reduced to a very low level. This will be appreciated when it is realised that in normal times before the war over eighty furnaces were in blast, whereas at the present time only seven are in blast. It is therefore not surprising that an effort is to be made to meet the competition of India-produced pig iron. To effect this it is understood that an important reconstruction scheme is to be carried out at the Gartsherrie Ironworks of William Baird and Co., Ltd., near Coatbridge, Lanarkshire. The company has decided to erect new blast-furnaces and coke-ovens at an estimated cost of about £1,000,000, and the work of reconstruction is to begin in the autumn of this year. The furnaces will be of the latest design, and will embody many distinctive features, while the new coke-oven plant will be one of the most modern types.

The scheme embraced by this reconstruction will assist considerably in increasing the productive capacity of the Scottish iron trade, and raise its economic efficiency; it gives an indication of a possible revival in the trade in Scotland, where the spell of depression has been very heavy.

Train Ferries to be Built at Wallsend

An important shipbuilding order has recently been secured by Messrs. Swan, Hunter, and Wigham Richardson, Ltd., of Wallsend-on-Tyne, the Southern Railway Co. having placed a contract for the construction of three train ferries. Each vessel will be capable of taking complete trains loaded with merchandise as well as sleeping coaches. They are to have a trial speed of 16½ knots and will have a length of about 360 ft., carrying four lines of rails on the train deck. On the upper decks will be the usual type of passenger accommodation, dining saloon, smoking room, private cabins, and, in addition, there will be an enclosed motor garage.

The engines will comprise a twin-screw arrangement of Parsons single-reduction geared turbines, which will be constructed by the Parsons Marine Steam Turbine Co., Ltd., at Wallsend. The boilers, which will be of the Yarrow water-tube type, to be built by Yarrow and Co., Ltd., of Scotstoun, Glasgow, are designed for a working pressure of about 250 lb. per sq. in., with a final superheated steam temperature of about 500° F. An interesting feature about the boilers is that they are designed to burn coal, for which purpose Taylor mechanical stokers are to be installed, an indication that both the modern steam turbine and coal as fuel for steam raising are still a competitive proposition as against oil-fired boilers and the Diesel engine.

High-Pressure Gas-Holder

A high-pressure gasholder, the first of its kind in the United Kingdom, has been erected to augment Skipton's gas storage capacity. The gasholder, erected by Newton, Chambers, Ltd., Thorncliffe, near Sheffield, is a steel cylinder with hemispherical ends. It is 102 ft. long, with a total height of 34 ft. and when full will hold a quarter of a million cubic feet of gas, with a pressure of 50 lb. per sq. in. The holder is connected to the gasworks by nearly a mile of piping.

Shipyard Demolition meets Opposition

The programme of the National Shipbuilders' Security in closing down shipyards and forbidding the sites to be used again for shipbuilding encountered an obstacle when the Sunderland Town Council decided to appeal to the Government for legislation making it illegal for a ground landlord to enter into any agreement restricting the future use of land adjoining waterways, which has been used for shipbuilding and kindred trades. It also requests other municipalities on the North-East Coast to pass similar resolutions. The Middlesbrough Town Council have decided to join in the North-East campaign against the National Shipbuilders' Securities, Ltd., in buying shipyards to dismantle, but one of the councillors pointed out that such a protest would have been useful about three years ago, before the plant was destroyed. Thus far the National Shipbuilders' Security has acquired twelve shipyards on the North-East Coast.

Stainless Steel in Dentistry

Research and experimental work carried out during the last few years at the Dental Department of the University of Sheffield, has shown the advantages of stainless steel when applied to dentistry. The results achieved are claimed to be convincing, and likely to lead to stainless steel displacing gold for the purpose. For some ten or twelve years stainless steel dentures made in Sheffield have been worn with the object of determining by actual experience to what extent the material would be applied. These have proved quite successful, but meanwhile further improvements have been made in the type of steel used and in its manipulation.

Austenitic steel is claimed to be suitable for dentures, impression trays, and instruments used for the mixing or insertion of cements and silicate fillings. It is also suitable for orthodontic appliances, clasps, and bands. Its greater strength in comparison with noble metals allow thinner plates to be used, and if the proper quality is chosen it offers advantages in regard to manipulation and cost. Some difficulty was at first experienced in soldering stainless steel for dental work, but spot-welding has now been adopted successfully at the University, where two machines have been specially designed to simplify the process. In these investigations Sheffield manufacturers of various stainless steels have assisted very considerably.

The work done at Sheffield University in this field has attracted the interest of other educational authorities, and it is of interest to note that Dr. G. H. Froggatt has been invited to give post-graduate lectures and demonstrations on stainless steel in dentistry at the University of Birmingham.

Increasing the Use of Aluminium Alloy in Motor-cars

Considerable interest is being aroused by tests now in progress with a specially built motor-car, in the construction of which alloys have been used that are unfamiliar to the average motor-car manufacturer. One alloy in particular, known as "Hiduminium," was introduced some years ago, and used in the construction of the Schneider Aero Trophy seaplanes, in which the crankcases, cylinder blocks, and cylinder heads were produced from this alloy. Various grades of this alloy were also used to a considerable extent in the construction of other Rolls-Royce engines used in record-breaking speed-boats.

The motor-car referred to is being tested on a journey to Constantinople over rough roads. It has a 30 h.p. six-cylinder engine, which is almost entirely built of this alloy; the exceptions being that the cylinder block will have cast-iron linings and the valve seatings and sparking-plug bosses will be of aluminium bronze. The series of alloys bearing the name of Hiduminium are not only lighter and tougher than alumunium alloys usually associated with motor-cars, but have many times their resistance to fatigue under the stress of heat and prolonged vibration, and the results of these tests will have a considerable influence on future progress in motor-car construction.

British Steel Merger Plan

Terms have been issued of a reorganisation scheme for the merging of the interests of Dorman Long and Co., Ltd., the South Durham Steel and Iron Co., Ltd., and the Cargo Fleet Iron Co., Ltd., which when carried out will consolidate the iron and steel industry of the North-East Coast. Designed to limit competition and to eliminate redundant plant, the merger will also have for its object the concentration of production in the most efficient plants of the companies, which will result in reduced operating costs and more effective selling of the manufactures.

The scheme involves a heavy reduction in capital, and holders of stocks and shares of Dorman Long and Co., Ltd., are asked to make heavy sacrifices in the capital reconstruction. Subject to its debenture and shareholders accepting the terms of the capital reconstruction put forward, Dorman Long and Co., Ltd., will acquire the South Durham Steel Co. and the Cargo Fleet Iron Co. It will bring under unified control practically the whole of the iron and steel industry in the Teeside and on the North-East Coast. Provision is made in the scheme for the creation of a quarter of a million of 5% redeemable stock, and the Banker's Industrial Development Co. has arranged for this finance.

Meetings of the shareholders will be held in London to consider the terms, those of the South Durham Steel Co. on July 19, and of Dorman Long and Co. on July 27.

Pease and Partners and Natural Mergers

Confidence in the reconstruction scheme of Pease and Partners, Ltd., was expressed by Mr. J. Frater Taylor, the chairman, at the company's annual meeting, held recently. So far as the first two months in this year are concerned, there has been an improvement in earnings as compared with the corresponding months of last year, despite the fact that outputs have been less. It is felt, however, that an iron and steel revival will not be felt until iron and steel are produced in more substantial and profitable quantities. Mr. Taylor stated that Thorne Colliery had contributed materially to the improvement made during the past year, but it could have done much better had it been free to raise and dispose of the greater output of which it was capable. Coal-cutting and conveying machinery is now being installed in the North-West district, and if it proves successful it is anticipated that consideration will be given to the mechanisation of other districts.

Apparently there is unnecessary and wholly unprofitable competition in the production and sale of coke. Obviously, it is futile to ensure minimum prices to a colliery in respect of its coal when there is an avenue of permissible loss open all the time in the production and sale of coke. There are natural mergers open to rival companies which would substantially solve such difficulties in connection with which Pease and Partners are prepared to take the initiative and become reasonably responsive to approaches by others.

Shipping Subsidies

The British delegation submitted proposals regarding shipping subsidies before the Sub-Committee of the World Conference which is discussing this subject. The main suggestions made were :—

(1) That State subsidies for the construction of shipping for, or its maintenance on, competitive routes, are uneconomic, can only lead to the granting of similar subsidies by other countries and/or to protective measures in respect of shipping, which would deprive world trade of the economic and efficient sea transport it has so far enjoyed, disorganise the world freight market, increase the burdens on national budgets, and lessen the power of maritime countries to pay in services for imports and loans.

(2) In these circumstances the countries concerned should move as rapidly as possible towards the diminution and ultimate abolition of State assistance to shipbuilding and ship operation on competitive routes.

The proposals were supported by Holland and Norway, and, with reservations, by Greece, Italy, and America. A further meeting was arranged at which the discussion is to be continued.

Tests on Aeroplane Float

Much interest is centred in tests to be carried out on two stainless steel seaplane floats, one welded and the other riveted, for which it is expected valuable information will be obtained. Some time ago Short Brothers (Rochester and Bedford), Ltd., constructed a riveted stainless steel float for the Air Ministry, and this firm have recently received an order to construct another of similar design and material, but to be fabricated by the spot-welding process, so that comparisons can be made to determine the most suitable form of construction.

Collapse of Antimony Trade Association

Although unsuccessful in its efforts to dominate the antimony trade in China, the newly organised Antimony Trade Association for Hunan did exercise considerable influence, notwithstanding predictions that it would soon collapse. A major development of the first quarter of the present year was the official announcement in March by the Hunan provincial government that it had withdrawn as an active participant in the association and would confine its interest to supervision. Numerous weaknesses were evident in the structure of the organisation, with or without government participation. The association was formed at the end of 1932 at Changsha by the various antimony interests, and was supported and controlled by the Hunan Government. It was intended to monopolise and control the production and export price of antimony from Hunan, but foreign dealers, well aware of heavy stocks in China and the probability of forcing down the price first fixed, declined to purchase until some members capitulated and business was resumed at lower levels. Another development of the first quarter of 1933 was an upward revision of the estimate of stocks available in the region.

United Steel Companies

In our April issue we had occasion to refer to what is believed to be a world's record set up by the United Steel Companies, Ltd., steel melting furnaces at their Appleby Iron Co., Ltd., plant at Scunthorpe. It applied more particularly to a 300-ton tilting furnace, from which a production of 2,595 tons of steel was obtained in six days. That this high rate of production is no mere flash-in-the-pan is indicated in a letter from the directors of the company to the staff, in which the statement is made that this plant is now producing more steel than ever, and that over 10,000 tons of steel has been produced in one month. It is noteworthy that during the last four years United Steel Companies have doubled their output of fine alloy steels.

British Standards Institution

Mr. Maurice F. G. Wilson, M.Inst.C.E., who has been Chairman of the Main Committee and Chairman of the General Council, in all for the past five years, has retired in accordance with the by-laws, and Mr. E. J. Elford, M.Inst.C.E., Borough Engineer and Surveyor of Wandsworth, past President of the Institution of Municipal and County Engineers, and Chairman of the Building Divisional Council, has been unanimously elected to succeed him as Chairman of the General Council for the next twelve months.

As Mr. Elford has been connected with the work for the past 20 years, is chairman of several committees, and a member of many others, it will be recognised that his long experience in the engineering profession is a full assurance that the guidance of the work of this national organisation is in excellent hands.

Catalogues and Other Publications.

In view of the rehabilitation of the iron and steel industry in this country, the new catalogues recently issued by the Willman Smith Owen Engineering Corporation, Ltd., will be of particular interest. One deals particularly with various types of furnaces, while another will appeal to users of cranes and other handling equipment. Both catalogues are exceedingly well produced, and a pleasure to handle; the text matter is informative, and the illustrations, of which there are many, are excellently produced. Those interested should apply for copies at the offices of the Corporation, Victoria Station House, Victoria Street, London, S.W. 1.

Rolling mills and forging presses now being built and installed embody many improved features that supply the need for greater accuracy and control, and the catalogue recently received from Davy Brothers, Ltd., Park Iron Works, Sheffield, deals with these types of plants. The object of this publication is to give a pictorial idea of the products of this old-established firm, an object which is achieved with credit; nevertheless, there is useful information which will be helpful to those about to install rolling mill and hydraulic machinery.

G. W. B. Electric Furnaces, Ltd., Elecfurn Works, North Road, Holloway, London, N. 7, has sent us two leaflets dealing with "Kleenard" open-hearth hardening compound and "Nokase" anti-carburising mixtures. It is of interest to note that "Nokase" mixtures are now supplied in clay, paint, or powder forms.

Friction clutches are in common use, and a necessity wherever machinery and line-shafting are installed, and engineers will be interested in the catalogue issued by Crofts (Engineers), Ltd., Thornbury, Bradford. It contains a range of proved designs for all power requirements, from small horse-power clutches to heavy duty types operated at powers as high as 5,000 h.p.

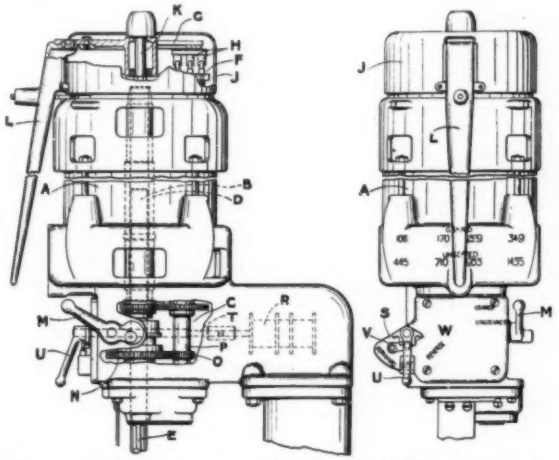
Imperial Chemical Industries, Ltd., Millbank, London, S.W. 1, have sent us a very attractive hand-book on the use of soda ash in the production of high-grade iron and steel castings. It gives full information on the method of treatment advised for various types of iron and steel work, and indicates the saving in cost which can be effected by the use of soda ash. Foundrymen should possess a copy of this admirable booklet.

Some Recent Inventions.

The date given at the end of an abridgment is the date of the acceptance of the complete Specification. Copies of Specifications may be obtained at the Patent Office, Sale Branch, 25, Southampton Buildings, London, W.C. 2, at 1/- each.

Electrically Driven Machine Tools

MANY machine tools are now directly operated by a variable-speed electric motor, usually a squirrel-cage asynchronous motor provided with pole-changing device, by which the different speeds can be selected. In such applications as at present constructed, the speed-control switching device has a zero position in which the supply of current to the motor is discontinued; but when the current is switched off the spindle continues to run for a considerable time, during which the operator cannot proceed with the work in hand. In order to overcome this disadvantage an improved arrangement of control has been devised. In addition to a speed-changing device, which is of the face-plate type and disposed on the top of the motor, the arrangement provides an independent forward stop and reverse switching means for the control of the motor.



The arrangement as applied to a drilling machine is shown in Figs. 1 and 2, in which a pole-changing squirrel-type induction motor, shown in outline at A, is used for driving the spindle B, either directly or through gearing such as the two-speed gearbox C, and the driven spindle has a splined or other driving and sliding connection with the rotor shaft D, this being hollow for the purpose. Alternatively, the sliding connection may be arranged between the lower part of the main spindle E and the associated splined gear sleeve.

The pole-changing device F is of the known face-plate kind, being mounted above the motor, and the rotatable disc G, carrying the usual sets of spring contact fingers H on its under surface (only one set being shown), is mounted for movement with a cover J for the same journalled on a peg K extending above the motor. A downwardly extending or other arm L fitted to the cover provides a convenient actuating lever, and its lower end co-operates with a line of "speed" numbers on the periphery of the frame at the lower end of the motor, as illustrated in Fig. 2, to indicate which of the particular speeds has been selected. Of the two lines of numbers, one line relates to the direct drive or ungeared speed, the other line to the geared speeds, when the gear lever M has been moved up to slide the gear N downwardly to mesh with the constantly driven gear O on the layshaft P.

A forward, off, and reverse switching means R, which is of a well-known type, is disposed in a casing S to the rear, and on one side, of the machine, and for actuating it use is made of a horizontal spindle T, terminating at its forward end with a handle U co-operating with a scale carrying some such words as "reverse," "off," "forward," as shown in Fig. 2, so that the handle lies over one of these words when the respective condition is obtained. A spring-pressed detent Y co-operating with a notched quadrant W may be associated with each of the switches for holding it in a set position.

Reference is also made to the application of this device to a lathe. By means of this improved arrangement it is claimed that the machine spindle is brought to rest almost instantaneously, independently of the speed at which it was being driven.

387,495. Sir Alfred Herbert, A. H. LLOYD, F. J. O. COXON, C. H. JINMAN, and E. W. TIPPLE, all of Alfred Herbert, Ltd., Coventry. February 9, 1933.

Beryllium and other Alloys

A PROCESS has been developed for the production of alloys, or combinations of metals of any kind. It consists in separating a metal from its combinations with an acid radical consisting of one kind of atom—*e.g.*, a halide—by a second metal which is to be alloyed with the first metal, the second metal entering into a volatile combination with the acid radical of the first metal compound. If a chloride of the first metal is to be reduced it may be prepared by the direct chlorination of the raw ore. In an example, beryllium chloride vapour is fed into a receptacle containing aluminium. Aluminium chloride is formed and escapes with some unreduced beryllium chloride from the reaction chamber, the reduced beryllium alloying with the excess of aluminium on the application of more heat. The beryllium particles liberated may be fused together instead of being alloyed with an excess of aluminium. The working conditions may be so chosen that the salt to be decomposed is partly solid in the reaction chamber, and the yield of reduced metal may be controlled by adjusting the conditions of temperature and pressure. The reaction may take place in currents of gases which are inert towards, or which participate partly or completely in, the reaction—*e.g.*, nitrogen, hydrogen, or rare gases such as argon, etc.; and such gases may serve to distil metals such as aluminium, magnesium, etc., into the reaction chamber, or to render non-volatile compounds produced by the reaction volatile during the process, as when beryllium sulphide is reduced in hydrogen, hydrogen sulphide being formed, leaving the beryllium in the chamber to alloy with the second metal. Similar reactions occur with azides when hydrogen is used. The working temperature may be so arranged, that the formation of the alloy takes place substantially or completely at the temperature of the reduction without additional heating. Heat for the initiation of the reduction and for its maintenance and for the alloying process may be supplied externally or by such means as the gases used in the process. The heat of the gases leaving the reaction chamber may be utilised by leading the gases around the reaction chamber. To utilise fully the heat developed during the reaction, the walls of the reaction chamber are made of suitable material, such as oxides of the metals taking part in the reaction, gold, platinum, iron, or nickel, or the walls may be plated with gold, platinum, etc.

386,621. W. KANGRO and A. LINDER, both of Brunswick, Germany.

Corrosion-resisting Iron Alloys

STAIN-RESISTING iron alloys having deep drawing properties contain 16–22% of chromium, 0·25–2·75% of copper, up to 0·3% of carbon, at least 3% of manganese, and at least 2% of nickel, the sum of the manganese and nickel being 6–14%. The alloys are free from or contain not more than 1% of tungsten and molybdenum. Alloys containing specified proportions of carbon, chromium, manganese, nickel, and copper within the above ranges, and also some containing no copper, are referred to. Specifications 309,841, 313,471, and 361,916 are rererred to.

388,057. ELECTROMETALLURGICAL CO., East 42nd Street, New York, U.S.A.

MARKET PRICES

ALUMINIUM.

98/99% Purity	£100	0	0

ANTIMONY.

English	£37 10 0 to £40	0	0
Chinese	27	10	0
Crude		—	

BRASS.

Solid Drawn Tubes	lb.	9¼d.
Brazed Tubes	„	11¼d.
Rods Drawn	„	8⅞d.
Wire	„	8d.
*Extruded Brass Bars	„	4⅝d.

COPPER.

Standard Cash	£38	5	0
Electrolytic	42	5	0
Best Selected	40	10	0
Tough	40	0	0
Sheets	68	0	0
Wire Bars	42	10	0
Ingot Bars	42	10	0
Solid Drawn Tubes	lb.	10¼d.	
Brazed Tubes	„	10½d.	

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	0	2	0
‡Ferro Tungsten	„	0	1	9
NOMINAL — Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
2–4% Carbon, scale 12/– per unit	ton	31	0	0
4–6% Carbon, scale 7/6 per unit	„	21	17	6
6–8% Carbon, scale 7/6 per unit	„	20	17	6
8–10% Carbon, scale 7/3 per unit	„	19	17	6
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 11/0 per unit	„	31	2	6
Guar. max. 1% Carbon, scale 13/6 per unit	„	35	2	6
§Guar. max. 0·7% Carbon, scale 15/– per unit	„	39	5	0
‡Manganese Metal 96–98% Mn.	lb.	0	1	2
‡Metallic Chromium	„	0	2	8
§ Ferro-Vanadium 25–50%	„	0	12	8
§ Spiegel, 18–20%	ton	7	10	0
Ferro Silicon—				
Basis 10%, scale 3/– per unit	ton	5	2	6
20/30% basis 25%, scale 3/6 per unit	„	7	17	6
45/50% basis 45%, scale 5/– per unit	„	12	17	6
70/80% basis 75%, scale 7/– per unit	„	18	17	6
90/95% basis 90%, scale 10/– per unit	„	30	0	0
§ Silico Manganese 65/75% Mn., basis 65% Mn.	„	14	17	6
§ Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	6
Ferro Phosphorus, 20–25%	ton	15	18	0
§ Ferro-Molybdenum, Molyte	lb.	0	5	6
§ Calcium Molybdate	„	0	5	4

FUELS.

Foundry Coke—			
S. Wales	£1 0 0 to 1	2	6
Scotland	— 1	8	0
Durham	1 1 0 to 1	5	0
Furnace Coke—			
Scotland	— 1	5	6
S. Wales	— 0	15	6
Durham	0 13 0 to 0	13	6

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)	£55	0	0
*Commercial Ingots	45	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0 9
*Cored Bars	„	0	0 11

LEAD.

Soft Foreign	£13	6	0
English	15	0	0

MANUFACTURED IRON.

Scotland—			
Crown Bars, Best	£10	5	0
N.E. Coast—			
Rivets	11	0	0
Best Bars	10	10	0
Common Bars	10	0	0
Lancashire—			
Crown Bars	9	15	0
Hoops £10 10 0 to	12	0	0
Midlands—			
Crown Bars £9 15 0 to	10	0	0
Marked Bars	12	0	0
Unmarked Bars		—	
Nut and Bolt Bars £6 15 0 to	7	10	0
Gas Strip	10	12	6
S. Yorks—			
Best Bars	10	10	0
Hoops £10 10 0 to	12	0	0

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	8d.
*Cored Bars	„	10d.
†Strip	„	10½d.
†Sheet to 10 W.G.	„	11d.
†Wire	„	1/0⅝
†Rods	„	11d.
†Tubes	„	1/4
†Castings	„	1/1½

†10% Phos. Cop. £30 above B.S.
†15% Phos. Cop. £35 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—			
Hematite M/Nos.	£3	6	0
Foundry No. 1	3	7	6
„ No. 3	3	5	0
N.E. Coast—			
Hematite No. 1	2	19	6
Foundry No. 1	3	5	0
„ No. 3	3	2	6
„ No. 4	3	1	6
Silicon Iron	3	5	0
Forge	3	1	6
Midlands—			
N. Staffs Forge No. 4	3	1	0
„ Foundry No. 3	3	6	0
Northants—			
Foundry No. 1	3	5	6
Forge No. 4	2	17	6
Foundry No. 3	3	2	6
Derbyshire Forge	2	19	0
„ Foundry No. 1	3	6	0
„ Foundry No. 3	3	3	6
West Coast Hematite	3	6	0
East „ „ No. 1	3	0	0

SWEDISH CHARCOAL IRON AND STEEL.

Kr. per English ton @ 18–16 to £1 approximately.

Pig Iron Kr. 90
Billets Kr. 230-290 £12 13 4–£16 0 0
Wire Rods Kr. 265-320 £14 12 6–£17 12 6
Rolled Bars (dead soft) Kr. 185-210 £10 4 0–£11 11 0
Rolled Charcoal Iron Bars Kr. 290 16 0 0
All per English ton, f.o.b. Gothenburg.

SCRAP METAL.

Copper Clean	£31	0	0
„ Braziery	28	0	0
„ Wire		—	
Brass	20	0	0
Gun Metal	26	0	0
Zinc	12	0	0
Aluminium Cuttings	74	0	0
Lead	12	10	0
Heavy Steel—			
S. Wales	2	5	0
Scotland	1	19	0
Cleveland	2	2	0
Cast Iron—			
Midlands	1	17	6
S. Wales	2	3	0
Cleveland	1	19	0
Steel Turnings—			
Cleveland	1	11	6
Midlands	1	5	0
Cast Iron Borings—			
Cleveland	1	2	0
Scotland	1	13	0

SPELTER.

G.O.B. Official		—	
Hard	£15	5	0
English	18	10	0
India	16	15	0
Re-melted	18	0	0

STEEL.

Ship, Bridge, and Tank Plates Scotland	£8	15	0
North-East Coast	8	15	0
Midlands	8	17	6
Boiler Plates (Land), Scotland	9	0	0
„ „ (Marine) „		—	
„ „ (Land), N.E. Coast	10	0	0
„ „ (Marine) „	10	10	0
Angles, Scotland	8	7	6
„ North-East Coast	8	7	6
„ Midlands	8	7	6
Joists	8	15	0
Heavy Rails	8	10	0
Fishplates	12	0	6
Light Rails £8 10 0 to	8	15	0
Sheffield—			
Siemens Acid Billets	9	2	6
Hard Basic £8 2 6 and	8	12	6
Medium Basic £6 12 6 and	7	2	6
Soft Basic	6	0	0
Hoops £9 10 0 to	9	15	0
Manchester Hoops £9 0 0 to	10	0	0
Scotland, Sheets 24 B.G.	10	5	0

HIGH SPEED TOOL STEEL.

Finished Bars 14% Tungsten	lb.	2/–
Finished Bars 18% Tungsten	„	2/9
Extras		
Round and Squares, ¼ in. to ½ in.	„	3d.
Under ¼ in. to 5/16 in.	„	1/–
Round and Squares 3 in.	„	4d.
Flats under 1 in. × ⅜ in.	„	3d.
„ „ ½ in. × ½ in.	„	1/–

TIN.

Standard Cash	£214	10	0
English	215	10	0
Australian	223	0	0
Eastern	216	10	0
Tin Plates I.C. 20 × 14 box	0	17	3

ZINC.

English Sheets	£26	0	0
Rods	30	0	0
Battery Plates		—	
Boiler Plates	25	5	0

* McKechnie Brothers, Ltd., quoted July 11. † C. Clifford & Son, Ltd., quoted July 11. ‡ Murex Limited, quoted July 11.

Subject to Market fluctuations. Buyers are advised to send inquiries for current prices.

§ Prices quoted July 11, ex warehouse.